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Reduction of Posterior Malleolus Fractures With Open Fixation Compared to Percutaneous Treatment

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Abstract

Background: Operative decision making between approaches to posterior malleolus reduction remains a challenge. The purpose of this study is to compare the quality of reduction between percutaneous and open reduction of posterior malleolus fractures and to identify factors associated with malreduction.

Methods: Operatively managed ankle fractures that included posterior malleolus fixation were reviewed. Fracture characteristics were determined on preoperative CT scans. Initial postoperative radiographs were used to measure reduction of the posterior malleolus articular surface and graded as satisfactory (<2 mm step-off) or malreduced (≥2 mm step-off). Final postoperative PROMIS scores and 1-year complications were compared between percutaneous and open cohorts. A multivariate stepwise regression model was used to evaluate predictors for malreduction.

Results: A total of 120 patients were included. Open reduction was performed in 91 (75.8%) compared with 29 (24.2%) who underwent percutaneous reduction. Malreduction (≥2-mm articular step-off) occurred in 11.7% of patients. Malreduction rates were significantly higher with percutaneous fixation than open fixation (24.1% vs 7.7%, $P = .02$). Multiple fragments and those with ≥5 mm of displacement demonstrated higher malreduction rates with percutaneous fixation ($P < .05$ for both), whereas single fragments and those with <5 mm of displacement experienced similar malreduction rates with percutaneous or open fixation. Initial displacement ≥5 mm (relative risk [RR] = 3.8, 95% CI = 1.2-11.5, $P = .02$) and percutaneous treatment (RR = 4.1, 95% CI = 1.6-10.5, $P < .01$) were identified as independent risk factors for malreduction. There were no significant differences in 1-year complication rates or final PROMIS scores between groups.

Conclusion: Open reduction of the posterior malleolus may lead to improved fracture reduction compared to percutaneous reduction without significant increase in complications. Open fixation improves reduction among fractures with multiple fragments or ≥5 mm of displacement, whereas fractures with a single fragment or <5 mm of displacement achieve similar reductions regardless of approach. Initial displacement ≥5 mm and percutaneous reduction are independent risk factors for malreduction.

Level of evidence: Level III, therapeutic.

Keywords: posterior malleolus, malreduction, approach, fracture morphology, PROMIS

Introduction

Posterior malleolus fractures are reported to occur in 7% to 44% of all ankle fractures.[1,15,23] Management of these fractures remains a challenge, and optimal treatment continues to be debated. Biomechanical studies have demonstrated the importance of the posterior malleolus for ankle stability, especially in the presence of concomitant lateral sided

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injuries.[10,19,21,28] Posterior malleolus fractures have also been reported to lead to increased tibiotalar contact stress and accelerated arthrosis.[9,12] As such, restoration of articular congruity and joint stability is of high importance in these injuries. Therefore, fixation of the posterior malleolus is traditionally recommended for fractures involving >25% of the articular surface and those with >2 mm of displacement.[7,13,14,20] Fracture characteristics such as multifragmentation, interposed fragments, involvement of the incisura, and concomitant ankle injuries also play a role in the treatment decision-making process.[2,3,24]

Numerous techniques exist for fixation of posterior malleolus fractures. Open reduction and internal fixation permits direct visualization of the fracture to facilitate anatomic reduction and improves the ability to address incarcerated fragments. This is frequently performed via a posterolateral (PL) approach with screw or plate fixation, whereas a posteromedial medial approach can be useful for fractures with medial extension.[7,18,20] These approaches often require prone positioning of the patient, which may complicate fixation of other injuries. Percutaneous or indirect reduction techniques are also commonly employed, often with placement of anterior-to-posterior lag or positional screw fixation. This permits a theoretical benefit of soft tissue sparing, which may reduce postoperative stiffness, and has a reduced operative time compared to open methods.[20] However, this limits its ability to directly assess joint congruity or address incarcerated fragments.

Prior investigations have reported superior fixation and outcomes with open fixation and plating compared to percutaneous screw fixation, whereas others have demonstrated similar outcomes between fixation methods.[17,23,27,30] However, literature comparing these reduction methods remains limited. Little is known about what factors may influence adequate reduction between open and percutaneous approaches. The purpose of this study was to compare radiographic rates of malreduction between percutaneous and open reduction of posterior malleolus fractures and to identify factors associated with malreduction. We also aim to compare postoperative outcomes for percutaneous and open reduction. We hypothesized that an open approach would lead to superior quality of reduction than percutaneous approaches.

Materials and Methods

Patient Population

Following institutional review board approval, a retrospective review of prospectively collected data was performed of adult patients who underwent operative management of an ankle fracture between 2010 and 2018. Patients were included if they were ≥18 years old and they underwent operative fixation of a posterior malleolus fracture in the setting of a rotational ankle injury. Patients with high-energy fracture patterns (ie, pilon fractures), concomitant tibial shaft fractures, or open or pathologic fractures were excluded. Patients without complete radiographic data available for review, including preoperative computed tomography (CT) scans, were also excluded. Preoperative CT scans were routinely obtained throughout the study period for evaluation of posterior malleolus fractures when surgical fixation was being considered. Details of the patient selection process are described in Figure 1. All patients were treated by orthopaedic surgeons (4 trauma fellowship trained, 3 foot and ankle fellowship trained) at a large, level 1 trauma, tertiary referral academic medical center. Foot and ankle surgeons performed 51.7% of the percutaneous reductions and 46.2% of the open reductions ($P = .60$). The indications for posterior malleolus fracture fixation included >25% articular surface involvement, ankle instability (with concomitant syndesmotic injury or persistent posterior talar subluxation), and/or ≥2 mm of displacement at the articular surface.[7,25]

Operative Technique

The choice between percutaneous vs open approach, as well as intraoperative positioning and surgical technique for posterior malleolus reduction, was based on the discretion of the treating surgeon. Of those who underwent an open reduction, the majority used a posterolateral approach (78%), with the others using a posteromedial (14%) or transfibular (7%) approach, and 1 patient underwent a dual posterolateral and posteromedial approach. In the open fracture reduction group, 82% were then fixed with a plate whereas 18% underwent screw fixation of the posterior malleolus fragment. In the percutaneous group, only indirect reduction methods were employed, such as manual closed reductions or percutaneous manipulations. In this group, about half were fixed with screws placed percutaneously from posterior to anterior (52%) whereas the remainder used anterior to posterior percutaneous screw placement.

Data Collection

Demographic information and intraoperative data were collected through review of patient medical records. Fixation of the posterior malleolus using a percutaneous vs open technique was recorded. All preoperative ankle radiographs and CT scans were reviewed to determine fracture characteristics including presence of multiple posterior malleolus articular fragments or presence of incarcerated/interposed fragments within the fracture site. Initial fracture displacement (millimeters of step-off at the articular surface) as well as the percentage of articular involvement (the ratio of the largest anterior to posterior diameter of the posterior malleolus fragment compared to total

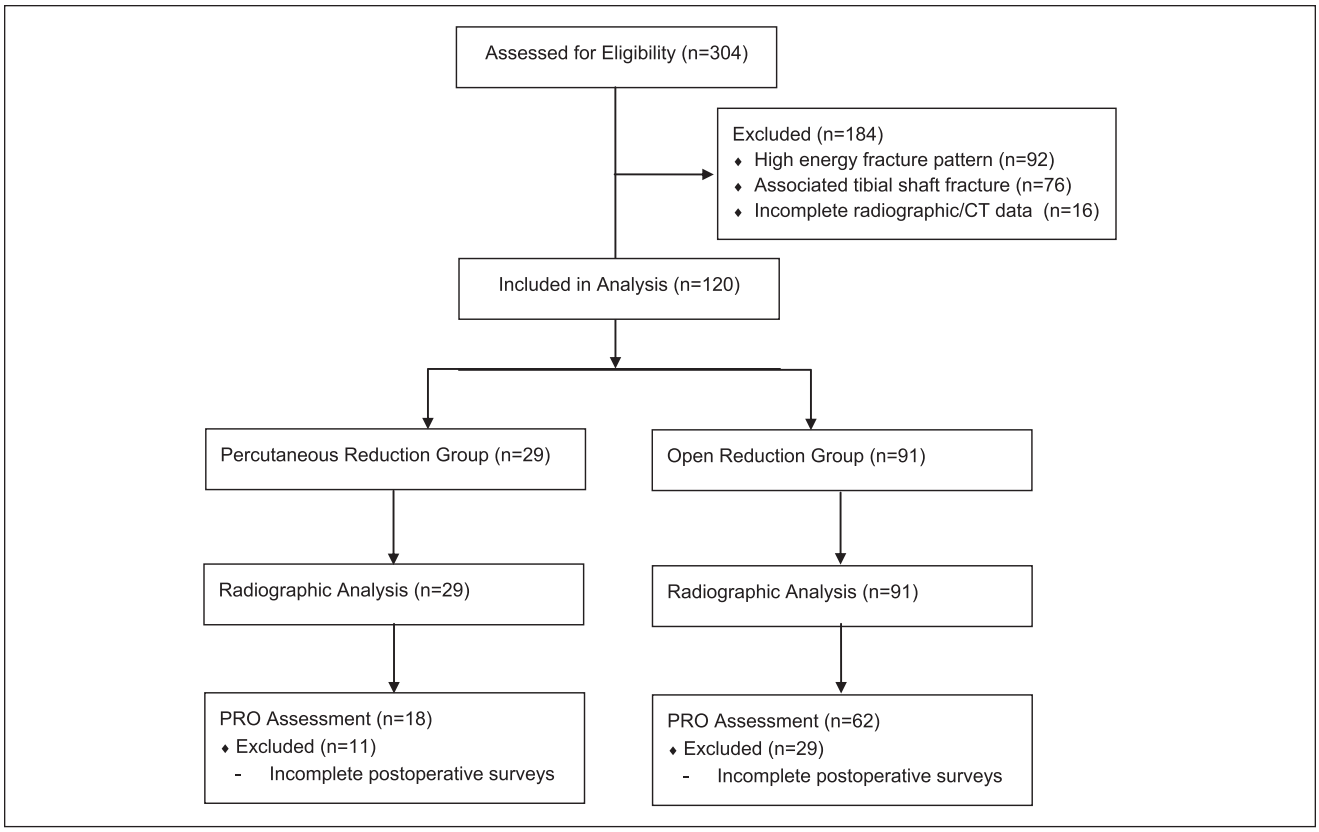

Figure 1. Flow chart detailing the patient selection process.

diameter of the plafond) was measured on the preoperative CT.[26] Initial postoperative radiographs were reviewed to evaluate the quality of the posterior malleolus articular surface reduction, graded as satisfactory (<2 mm step-off at the articular surface) or malreduced (≥2 mm step-off).[10,29] Image quality and rotational profile was assessed for all radiographs and was deemed to be appropriate. Radiographic measurements were performed by 2 investigators in duplicate who were not involved in the surgeries with excellent interobserver and intraobserver agreement for all measurements (Pearson correlations of r=0.945-0.979 and r=0.922-0.996, respectively). Reviewers were masked to the fixation method while completing preoperative measurements.

All surgical complications that occurred during the first postoperative year were recorded and included symptomatic implants requiring removal, revision of fixation for implant failure or nonunion, conversion to arthrodesis after implant failure or development of posttraumatic arthritis, deep surgical site infection requiring surgical debridement, and ankle impingement/synovitis requiring surgical management. Radiographic evidence of malreduction or posttraumatic arthritis in isolation was not included as a complication unless surgical intervention was required. Patient-reported outcomes (PROs) were assessed at final follow-up and included Patient-Reported Outcomes Measurement Information System (PROMIS) physical function, pain interference, and depression domains. Patients without PRO data at a minimum of 6 months postoperatively were excluded from the PRO analysis.[4]

Statistical Analysis

Statistical analysis was performed using Stata/SE 17.0 for Mac (StataCorp LP, College Station, TX). Univariate methods including χ^2 analysis and independent t tests were used to compare characteristics between percutaneous and open fixation cohorts. The association of fixation technique with malreduction rates was assessed using Fisher exact test. Independent risk factors for posterior malleolus malreduction were identified using a multivariate, stepwise Poisson regression with robust error variance, initially including all potential factors (age ≥60 years, male gender, interposed/incarcerated fragment, multiple fragments, ≥25% articular involvement, displacement ≥5 mm, and percutaneous fixation) and sequentially removing those with the highest P value until only significant factors remained. Independent t tests and Fisher exact tests were used to compare complications and PROs between the percutaneous and open fixation cohorts. Statistical significance was set at $P<.05$.

Table 1. Population Characteristics.[a]

	Percutaneous (n=29)	Open (n=91)	*P* Value[b]
Age, y, mean ± SD	56.4 ± 17.3	49.1 ± 17.1	**.046**
Sex			.34
Male	27.6 (8)	37.4 (34)	
Female	72.4 (21)	62.6 (57)	
Multifragmented	55.2 (16)	55.0 (50)	.98
Interposed/incarcerated fragment	41.4 (12)	50.5 (46)	.39
≥25% articular involvement	65.5 (19)	62.6 (57)	.78
Initial displacement ≥5 mm	31.0 (9)	51.7 (47)	.053

[a]Unless otherwise indicated, values are n (%).
[b]Boldface indicates statistical significance. *P* values were calculated using independent *t* tests (continuous) and χ^2 analysis (categorical).

Results

A total of 120 patients who underwent fixation of a posterior malleolus fracture (age range 19-84 years) were included in the analysis with an average postoperative follow-up of 43 weeks. ORIF of the posterior malleolus was performed in 91 patients (75.8%) compared to 29 patients (24.2%) who underwent percutaneous reduction and fixation (Table 1). On average, patients that underwent percutaneous fixation of the posterior malleolus were older than those managed with open fixation (56 ± 17 years vs 49 ± 17 years, $P = .046$). The incidence of multifragmented fractures (percutaneous = 55.2%, open = 55.0%), incarcerated fragments (percutaneous = 41.4%, open = 50.5%), and ≥25% articular surface involvement (percutaneous = 65.5%, open = 62.6%) were similar between percutaneous and open groups ($P > .05$ for each). Fractures with initial displacement ≥5 mm were more likely to be treated with open reduction, although this did not reach statistical significance (open = 51.7%, percutaneous = 31.0%; $P = .053$).

Malreduction of the posterior malleolus was identified in 11.7% of patients (Figure 2). Malreduction rates were significantly higher among those treated percutaneously than those treated with open fixation (percutaneous = 24.1%, open = 7.7%; $P = .02$). Subanalyses based on various fracture characteristics were performed to further evaluate differences in malreduction rates (Table 2). Multifragmented fractures demonstrated a significantly higher malreduction rate with percutaneous fixation (percutaneous = 31.3%, open = 6.0%; $P = .02$), whereas single fragment fractures experienced similar malreduction rates regardless of fixation type ($P = .62$). Fractures with ≥5 mm of initial displacement demonstrated significantly higher malreduction rates with percutaneous fixation (percutaneous = 55.6%, open = 10.6%; $P < .01$), whereas fractures with <5 mm displacement had similar malreduction rates with both fixation methods ($P = .58$). In the presence of incarcerated fragments, there was a trend toward a higher rate of malreduction after percutaneous fixation compared to open fixation but this did not reach statistical significance (33.3% vs 10.9%, $P = .07$). No significant differences in malreduction rates were detected between open and percutaneous fixation among fractures without interposed fragments, or among those with or without ≥25% articular involvement ($P > .05$ for all).

Figure 2. Representative case image of a posterior malleolus fracture with persistent malreduction (≥2 mm articular step-off) after percutaneous reduction and lag screw fixation.

On multivariate analysis, initial displacement ≥5 mm (relative risk [RR] = 3.8, 95% CI = 1.2-11.5, $P = .02$) and percutaneous fixation (RR = 4.1, 95% CI = 1.6-10.5, $P < .01$) were identified as independent risk factors for malreduction of the posterior malleolus (Table 3). No other associations were detected between other fracture characteristics including age, sex, incarcerated fragments, multifragmentation, and ≥25% articular involvement, and risk for malreduction ($P > .05$ for all).

Table 2. Rates of Malreduction.

	Malreduction Rate		
	Percutaneous, % (n/N) (n=29)	Open, % (n/N) (n=91)	*P* Value[a]
Overall	24.1 (7/29)	7.7 (7/91)	**.02**
Multiple fragments	31.3 (5/16)	6.0 (3/50)	**.02**
Single fragment	15.4 (2/13)	9.8 (4/41)	.62
Large articular fragment (≥25%)	26.3 (5/19)	8.8 (5/57)	.11
Small articular fragment (<25%)	20.0 (2/10)	5.9 (2/34)	.22
Displaced fractures (≥5mm)	55.6 (5/9)	10.6 (5/47)	**<.01**
Mild displacement (<5mm)	10.0 (2/20)	4.6 (2/44)	.58
Interposed/incarcerated fragment	33.3 (4/12)	10.9 (5/46)	.07
No interposed/incarcerated fragment	17.7 (3/17)	4.4 (2/45)	.12

[a]Boldface indicates statistical significance. *P* values calculated using Fisher exact test.

Table 3. Multivariate Analysis for Malreduction.

	Malreduction Rate, %	RR	95% CI	*P* Value[a]
Total	11.7			
Initial displacement				
<5 mm	6.3	Ref.		
≥5 mm	17.9	3.8	1.2-11.5	**.02**
Fixation type				
Open	7.7	Ref.		
Percutaneous	24.1	4.1	1.6-10.5	**<.01**

Abbreviations: Ref., referent; RR, relative risk.
[a]Boldface indicates statistical significance. *P* value calculated using a stepwise, multivariate Poisson regression with robust error variance evaluating age ≥ 60 years, male gender, interposed/incarcerated fragment, multiple fragments, ≥ 25% articular involvement, displacement ≥5 mm, and percutaneous fixation as potential risk factors.

Table 4. Outcomes for Posterior Malleolus Fractures After Percutaneous or Open Reduction.

	Percutaneous (n=29)	Open (n=91)	*P* Value[a]
Complications, % (n)	10.3 (3)	16.5 (15)	.56
Removal of symptomatic implants	3.4 (1)	7.7 (7)	
Conversion to arthrodesis	3.4 (1)	3.3 (3)	
Revision of fixation	3.4 (1)	1.1 (1)	
Deep infection/ wound dehiscence	0.0 (0)	3.3 (3)	
Ankle impingement/ synovitis	0.0 (0)	1.1 (1)	
Final PROMIS scores, mean ± SD			
Physical function	41.9 ± 7.7	43.0 ± 6.9	.56
Pain interference	53.8 ± 10.1	54.7 ± 7.9	.68
Depression	47.1 ± 11.6	48.6 ± 10.5	.60

[a]*P* values were calculated using independent *t* tests (continuous) and Fisher exact test (categorical).

Outcomes following percutaneous and open fixation of posterior malleolus fractures are detailed in Table 4. No differences in complication rates over the first postoperative year were observed between groups (percutaneous = 10.3%, open = 16.5%; $P = .56$). The most common complication was symptomatic implant requiring removal (percutaneous = 1, open = 7), with only 1 patient requiring removal of a posterior plate whereas the remainder underwent removal of syndesmotic screws (n = 4), medial screws (n = 2), or fibular plate plus syndesmotic screw (n = 1). Additional complications included conversion to arthrodesis (percutaneous = 1, open = 3), revision fixation (percutaneous = 1, open = 1), deep surgical site infection (open = 3), and ankle impingement requiring arthroscopic debridement (open = 1).

A total of 80 patients (percutaneous = 18, open = 62) had final follow-up PRO data at 6 months or later (average = 12.4 ± 9.4 months, range = 6-60 months). Among these, PROMIS physical function (41.9 vs 43.0, $P = .56$), PROMIS pain interference (53.8 vs 54.7, $P = .68$), and PROMIS depression (47.1 vs 48.6, $P = .60$) scores at final follow-up were similar between percutaneous and open groups, respectively.

Discussion

This study demonstrated that an open surgical approach to the posterior malleolus in the setting of low-energy ankle fractures was associated with improved fracture reduction compared to percutaneous reduction techniques without a significant difference in complication rates. Open fixation significantly improved fracture reduction among those with

multiple fragments or ≥5 mm of displacement. In contrast, fractures with only a single fragment and those with <5 mm of displacement were able to achieve similar reductions with percutaneous or open approaches. Finally, initial displacement ≥5 mm and percutaneous reduction were identified as independent risk factors for malreduction.

Although open reduction and fixation of the posterior malleolus did not result in a significant increase in complication rates, there are some disadvantages. Prone positioning is often required for the PL approach, which can make fixation of associated medial malleolus fractures more challenging. In cases of associated injuries or polytraumas, repositioning of the patient may be needed to address injuries that are often not accessible from the prone position. Therefore, the identification of fractures that may require an open reduction is important during preoperative planning to anticipate intraoperative positioning needs. Furthermore, a direct approach requires more significant soft tissue disruption, increasing the potential for nerve injury, wound healing problems, or postoperative stiffness.[7] Careful soft tissue management remains an important consideration to optimize surgical outcomes. As such, it is helpful to understand which fractures most benefit from open fixation and which ones may achieve similar results with percutaneous methods. Future investigations may be useful to explore other potential differences between reduction approaches, such as surgical time, ankle motion, or maintenance of reduction.

In the present study, open fixation significantly improved reduction quality among multifragmented fractures and those with displacement ≥5 mm. Similarly, when an interposed fragment was present, open fixation trended toward a higher rate of accurate reduction although this did not reach statistical significance ($P = .07$). It is likely that indirect reduction via ligamentotaxis is insufficient in these scenarios and therefore open fixation would be preferred. Furthermore, fractures with ≥5 mm displacement leads to an almost 4-fold increase in risk for malreduction. Although 2 mm of displacement may be the traditional indication for fixing posterior malleolus fractures, significant displacement ≥5 mm may be a valuable indicator of the need for open reduction and fixation. Conversely, in fractures with a single fragment or displacement <5 mm, percutaneous and open fixation achieved similar rates of acceptable reduction. As such, these fractures may be more amenable to percutaneous fixation if that approach is otherwise preferred.

Preoperative CT scans are important in evaluating fracture morphology, as multifragmentation is often not visualized on plain radiographs and fracture displacement can be underrepresented.[5,8,16] In the current investigation, 63% of multifragmented fractures were only visualized on CT but not on radiographs. Prior studies have also demonstrated the importance of CT scans in these injuries, with one report indicating a change in operative approach or positioning 44% of the time after reviewing CT images, and another reporting change in surgical approach 32.7% of the time and specifically a change in the management of the posterior malleolus 25.6% of the time.[6,22] This highlights the importance of CT scans for accurate evaluation of fracture morphology during surgical planning.

Despite the improvement in fracture reduction in the open fixation cohort compared to percutaneous fixation, no differences in PROMIS scores were observed at final follow up. Literature comparing clinical outcomes between open and percutaneous fixation remains limited. Shi et al[23] demonstrated higher American Orthopaedic Foot & Ankle Society ankle-hindfoot scores with direct reduction compared to indirect reduction, but similar visual analog scale scores. O'Connor et al[17] reported superior Short Musculoskeletal Function Assessment bother index scores after PL plating compared to percutaneous anterior-to-posterior screws. As PROMIS is a more global measure of pain and physical function, it may not be as sensitive for the detection of subtle differences in postoperative ankle function.[11] It is possible that this global nature of PROMIS contributed to a lack of appreciable differences between groups or that longer follow-up may be needed to detect differences with PROMIS. However, PROMIS is a validated PRO measure and, as such, may be more reliable than other commonly used surveys. Given the variability in reported results with limited sample sizes, and inconsistency in PROs used, the effect of fixation technique on clinical outcomes for posterior malleolus fractures remains unclear.

This study is not without limitations. Treatment decision making as well as intraoperative assessment of reduction adequacy was at the discretion of each surgeon and likely multifactorial in nature with consideration of other factors such as fracture pattern and morphology, additional injuries, personal preferences, soft tissue status, preexisting arthritis, or degree of residual displacement. In addition, the relatively small size of the percutaneous cohort and low incidence of malreduction and complications prevented our ability to perform additional subanalyses and increases the possibility of type II error. Patients without a preoperative CT scan were excluded, introducing an element of selection bias. However, preoperative CT scans were routinely obtained for these injuries during the study period, with only rare exceptions. Further, postoperative CT scans were not routinely obtained, so the quality of reduction was assessed on radiographs. This may have limited our ability to precisely quantify residual displacement. Although the primary focus of this study was on early radiographic outcomes, our analysis of long-term outcomes is limited by missing PRO data at the 12-month time point or later. However, previous studies have suggested that there is little further improvement in physical function after the 6-month time point following ankle fracture fixation.[4,11] Further work is needed to longitudinally evaluate patient-reported

outcomes and long-term clinical outcomes between percutaneous and open fixation techniques. Despite these limitations, this study provides valuable information to aid in surgical planning for posterior malleolus fractures and lays a foundation for future investigations.

Conclusions

This study demonstrated that an open surgical approach to the posterior malleolus in the setting of low-energy ankle fractures was associated with improved fracture reduction compared to percutaneous reduction techniques without a significant difference in complication rate or PROs. In particular, fractures with multiple fragments or ≥5 mm of displacement may result in improved fracture reduction when an open approach is used. However, fractures with only a single fragment and those with <5 mm of displacement may achieve similar reductions with percutaneous or open fixation. Finally, initial displacement ≥5 mm and percutaneous fixation were identified as independent risk factors for malreduction. This study also highlights the utility of a preoperative CT scan to better assess the morphology of the posterior malleolus as comminution and interposed fragments were common findings that may impact surgical decision making and are difficult to assess on plain radiographs.

Ethical Approval

Ethical approval for this study was obtained from the University of Rochester Research Subjects Review Board (RSRB00060987)

Declaration of Conflicting Interests

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