

Direct versus indirect posterior malleolar fixation in the treatment of trimalleolar ankle fractures: Is there a difference in outcomes?

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Abstract

Purpose: The purpose of this study was to examine the differences in functional outcomes between direct and indirect surgical fixation methods of the posterior malleolus in the setting of trimalleolar fractures and identify any variables affecting patient outcomes.

Methods: Primary outcomes were evaluated by PROMIS scores for short-term outcomes regarding total pain (TP) and total function (TF) comparing 40 patients with direct fixation with 77 with indirect fixation. Continuous variables were analyzed using t tests for parametric variables and the Mann-Whitney *U* test for nonparametric variables. Categorical variables were analyzed using a χ^2 test. Univariate and multivariate linear regression models were performed to analyze factors that affect outcomes of TP and TF.

Results: There was no difference in TP or TF between groups ($P = 0.65$ vs. $P = 0.19$). On univariate linear regression for TP, BMI, incidence of complication, tobacco use, and open injury showed significance in increasing pain levels with open injuries providing the greatest effect (coef = 11.8). On multivariate analysis, BMI, incidence of complication, open injury, and tourniquet time all significantly increased pain. For TF, univariate analysis showed age, BMI, incidence of complication, and diabetes to decrease function, and use of external fixator and tourniquet time increased function. In the multivariate model, increased BMI, open injuries, and increasing tourniquet time all decreased TF while use of an external fixator increased TF.

Conclusion: This study showed no difference in TP and TF using the PROMIS outcome scores when comparing direct fixation versus indirect fixation under univariate and multivariate models.

Level of Evidence: Therapeutic III.

Keywords: trimalleolar fracture, direct fixation, indirect fixation, posterior malleolar fragment

1. Introduction

Trimalleolar fractures make up approximately 10% of all ankle fractures with increasing incidence because of widespread participation in sports activities and an evergrowing elderly population.^[1] Most of these injuries occur from falls from standing height or rotational mechanisms and can be associated with dislocations of the ankle joint or other injuries to the lower extremity. When addressing trimalleolar fractures, there are numerous factors that affect the decision to fix posterior malleolus fragments, such as fragment size,

syndesmotic stability, articular impaction, and comminution.^[2,3] To reduce the incidence of long-term arthritis and to restore anatomic articular congruency, it has been cited that a posterior malleolus fragment size exceeding 25%–33% of the articular surface indicates the need for fixation.^[4,5] Alternatively, a survey conducted among fellowship trained orthopaedic foot and ankle surgeons and fellowship trained orthopaedic foot and ankle surgeons indicated that fragment size was not the primary indication for fixation, but rather fracture stability.^[6] Currently, there is no consensus to fix the posterior malleolus component, and the debate extends into whether to fix it directly with screws or plate and screws or indirectly through reduction and fixation of the syndesmosis.

The posterior malleolus serves as the attachment site for the posterior inferior tibiofibular ligament (PITFL) which provides rotatory stability to the ankle joint through the syndesmosis. The association of fixing the posterior malleolus fragment and restoring the syndesmosis is well-established in part due to the PITFL and the distal tibiofibular joint.^[7] The distal tibiofibular syndesmosis is essential for supporting the joint and maintaining mortise congruency.^[8] Without reduction of the posterior malleolar fragment and thus the syndesmosis, the joint is at increased risk for long-term complications such as pain, ankle instability, and arthritis.^[9] Additional benefits to restoring syndesmotic stability by fixing the posterior fragment include restoration of the articular surface of the tibia, aiding in attaining length of the fibula^[10] and decreased risk of malunion. Based on this anatomical relationship, the overall goal of restoring ankle joint congruency and stability can be achieved by fixing the posterior malleolus, but few studies have evaluated the functional outcomes when using direct versus indirect fixation to address the inherent instability of these injuries.^[10,11]

The authors report no conflict of interest.

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Figure 1. AP, mortise, and lateral injury films and 1 month postoperatively. Injury films demonstrate a trimalleolar fracture with a sizable posterior malleolus fragment. Direct fixation allows for anatomic reduction of the posterior malleolus.

In cases of trimalleolar fractures that require operative fixation of the posterior malleolus fragment, the decision to perform direct versus indirect reduction and fixation is still in question. The focus of this study was to examine the differences in functional outcomes between direct and indirect surgical fixation methods of the posterior malleolus and identify any demographic or perioperative variables affecting patient outcomes in pain and function in the setting of trimalleolar fractures.

2. Materials and methods

2.1. Study design

This was a multicenter retrospective cohort study of patients who underwent open reduction internal fixation (ORIF) for a diagnosis of trimalleolar ankle fracture or a bimalleolar ankle fracture with a syndesmotic injury (trimalleolar fracture equivalent) by fellowship

trained orthopaedic trauma surgeons from March 2015 to October 2019. These patients were identified by searching institutional databases for the Current Procedural Terminology (CPT) codes of 27822 and 27823. All ankle fractures were confirmed radiographically, and only fractures that were of AO/OTA 44A/B/C classification (with posterior malleolus subtypes) were included for analysis. Western Institutional Review Board (WIRB) approval (Protocol #20171537, principal investigator: Frank A. Liporace) was obtained before study initiation and informed consent was obtained from all patients included in the study.

The goal was to compare direct fixation, using direct exposure and reduction with screw or plate fixation of the posterior malleolus fragment (Fig. 1), with indirect reduction and fixation through stabilization of the syndesmosis without directly reducing the posterior malleolus and creating stabilization with the PITFL (Fig. 2). The primary outcome of interest was short-term



Figure 2. AP, mortise, and lateral injury films and 1 month postoperatively. Injury films demonstrate a trimalleolar fracture dislocation. Postoperative films show anatomic reduction of the ankle mortise and an indirect reduction of the posterior malleolus.

patient-reported PROMIS scores for total pain (TP) (Pain Interference—Short Form 8a) and total function (TF) (Physical Function—Short Form 10b) postoperatively. The scale on which these scores are based on is reflective of the TP and TF the patient is feeling (ie, higher TP score is equivalent to a higher pain experience, and higher TF score is equivalent to a higher functional experience). Secondary outcomes included finding factors that increase and decrease patient pain and function after ORIF for trimalleolar ankle fractures.

2.2. Patient demographics

Institutional trauma registries were screened for inclusion. Exclusion criterion was patients with less than 1-year follow-up.

A total of 126 patients who underwent ORIF for trimalleolar ankle fracture or trimalleolar fracture equivalents between March 2015 and October 2019 were identified. Patient demographic, perioperative, and postoperative variables were collected by reviewing the electronic medical records. Nine of these patients did not have sufficient follow-up, and PROMIS scores were not obtainable and, therefore, were excluded from analysis. PROMIS scores were obtained through phone conversation with the patient, and this was considered the patients' final follow-up time point. This left 117 patients who comprised the final study cohort: 40 in the direct fixation group and 77 in the indirect fixation group. The groups did not differ for age or sex ($P = 0.12$ and $P = 0.12$) but did significantly differ for BMI and presence of comorbidities ($P = 0.03$ and 0.02 , respectively; Table 1).

TABLE 1
Head-to-Head Comparison Between DF and IF of the Posterior Malleolus for ORIF.

	Results		
	(% for categorical, ± SD for continuous)		
	Direct	Indirect	P
N	40	77	
Age	47.9 ± 19.0	53.5 ± 18.2	0.12
BMI	28.3 ± 6.7	31.4 ± 7.4	0.03
Sex	87.5% F	75.3% F	0.12
Follow-up time (mos)	26.1 ± 20.9	30.4 ± 19.6	0.27
Complications	15.0%	22.1%	0.36
Flap	2.5%	2.6%	0.98
Workers' compensation	5.0%	1.3%	0.23
Tobacco	7.5%	16.9%	0.16
Diabetes	10.0%	16.9%	0.32
Open fracture	5.0%	2.6%	0.50
DVT prophylaxis	42.5% ASA 325	46.8% ASA 325	0.28
Ethanol on injury	0%	2.6%	0.30
Comorbidities	76.60%	57.50%	0.03
Posterolateral approach	75.00%	1.30%	<0.001
External fixator	35.00%	20.80%	0.10
Syndesmotic fixation	12.50%	87.80%	<0.001
Tourniquet time	100.5 ± 45.6	86.8 ± 41.5	0.11
TP	47.9 ± 8.0	48.7 ± 9.8	0.65
TF	47.0 ± 12.6	44.5 ± 10.6	0.19

Bolded entries indicate between group comparisons that reached statistical significance.

2.3. Surgical technique and postoperative protocols

All fractures were treated with open reduction and internal fixation. If the soft tissue envelope was compromised at initial injury, an external fixator was first placed to allow for swelling to diminish. Lateral malleolus fractures were treated with a lag screw when amenable along with plate fixation. A bridging construct was used in comminuted fracture patterns that could not be fixed by using a lag technique. Medial malleolus fractures were treated with 2 cannulated screws perpendicular to the fracture line, an antiglide plate, or an internal brace in purely ligamentous injury. Every case involved an intraoperative cotton test to determine syndesmotic stability after medial and lateral malleolus internal fixation. In all cases, “plan A” of the senior surgeon was to obtain direct reduction and fixation of the posterior malleolus fragment. This was performed using either plate fixation or anterior to posterior screw fixation. Screws were used only when all of the screw threads on 3.5 mm partially threaded screws were able to cross the fracture line.

All patients were strictly non-weight-bearing for 6 weeks. After 2 weeks, stitches were removed, and patients initiated physical therapy including passive, active assist, and active range of motion exercises. At 6 weeks, patients were transitioned to a fracture cam-boot and began partial weight-bearing. Full weight-bearing was allowed at 12 weeks. Both institutions used the same postoperative protocols for their fracture patients.

2.4. Statistical analysis

Baseline characteristics were compared including patient demographic, comorbidity, perioperative, and postoperative variables between direct fixation (DF) and indirect fixation (IF) groups. To compare between groups, continuous variables were analyzed using independent t tests for parametric variables and the Mann-Whitney U test for nonparametric

TABLE 2
Regression Model Analyzing the Whole Cohort for Dependent Variable of TP and TF.

	Variable	Linear Regression Model			
		Univariate	P	Multivariate	P
TP	Age	0.017	0.71	—	
	BMI	0.27	0.02	0.27	0.02
	Sex	-2.65	0.21	—	
	Complications	5.03	0.02	3.92	0.05
	Flap	-5.47	0.31	—	
	Workers' compensation	-7.93	0.14	-6.42	0.19
	Tobacco	4.80	0.05	3.42	0.14
	Diabetes	3.76	0.12	2.02	0.40
	Open fracture	11.8	0.01	13.22	0.003
	Ethanol on injury	6.23	0.35	—	
	Comorbidities	2.98	0.11	0.25	0.89
	Posterolateral approach	1.48	0.45	—	
	External fixator	-1.69	0.39	—	
	Syndesmotic fixation	-1.74	0.32	—	
TF	Tourniquet time	0.063	0.001	0.05	0.008
	Direct fixation	-0.82	0.65	0.41	0.82
	Age	-0.15	0.006	-0.10	0.10
	BMI	-0.30	0.04	-0.31	0.03
	Sex	3.41	0.20	0.93	0.70
	Complications	-6.28	0.02	-4.49	0.07
	Flap	3.23	0.63	—	
	Workers' compensation	5.08	0.45	—	
	Tobacco	-3.44	0.26	—	
	Diabetes	-6.14	0.04	-0.36	0.90
	Open fracture	-9.79	0.09	-12.62	0.02
	Ethanol on injury	-3.31	0.68	—	
	Comorbidities	-7.10	0.002	-2.07	0.39
	Posterolateral approach	0.91	0.70	—	
External fixator	5.48	0.02	6.91	0.003	
Syndesmotic fixation	1.03	0.63	—		
Tourniquet time	0.06	0.001	-0.064	0.005	
Direct fixation	2.47	0.27	0.70	0.75	

Bolded entries indicate between group comparisons that reached statistical significance.

variables while categorical variables were analyzed using a χ^2 test. Normality was established by testing the equality of standard deviations between groups. Statistical significance was set at $P < 0.05$. In addition, univariate and multivariate linear regression models were fit to look at which factors might affect TP and TF. Factors analyzed were included in the multivariate regression model if the univariate P-value was <0.2 . Both PROMIS scores were included in multivariate analysis because this was the primary outcome, regardless of statistical significance. Stata/IC v16.1 (College Station, TX) was used for all statistical analyses.

3. Results

All factors that were compared between groups are shown in Table 1. Of note, groups differed for the use of posterolateral approach to the ankle and use of syndesmotic fixation, a higher BMI in the indirect group, and a higher rate of comorbidities in the direct group. The DF group had a greater use of the posterolateral approach ($P < 0.001$) because of the need to directly fixate the posterior malleolus in the final construct. Similarly (and not surprisingly), the IF group had a greater use of syndesmotic fixation ($P < 0.001$) because this strategy is used to stabilize the ankle and reduce the posterior malleolus without directly fixing the posterior malleolus. There was no difference in

TABLE 3
Surgical Complications Seen in Our Patient Cohort.

Complications	Indirect	Direct
Painful hardware	4	2
Wound dehiscence	4	0
Post-traumatic arthritis	3	1
Nonunion	2	0
Complex regional pain syndrome	1	1
Subsequent trauma	1	0
Exposed hardware requiring flap	1	0
Malreduction	1	0
Infection	0	1
Morton neuroma	0	1

TP between groups (D = 47.9 ± 8.0, I = 48.7 ± 9.8; P = 0.65) or TF (D = 47.0 ± 12.6, I = 44.5 ± 10.6; P = 0.19).

Statistically significant results for affecting TP (Table 2) on univariate linear regression include BMI, complications, tobacco use, open injury, and tourniquet time. Patients with a higher BMI had significantly more pain (coef = 0.27, P = 0.02), as well as patients suffering open fractures (coef = 11.8, P = 0.01). Patients who had complications arise such as infection, secondary surgery, or fixation failure also had higher pain scores (coef = 5.03, P = 0.02). Tobacco use (coef = 4.8, P = 0.05) and increased tourniquet times (coef = 0.063, P = 0.001) were shown to increase pain scores as well. On multivariate analysis, BMI, complications, open injuries, and longer tourniquet times were statistically significant predictors for increased TP. Once again, fixation type was not statistically significant when comparing pain scores (coef = 0.41, P = 0.82).

For TF (Table 2), the univariate analysis showed age (coef = -0.15, P = 0.006), BMI (coef = -0.3, P = 0.04), complications (coef = -6.28, P = 0.02), diabetes (coef = -6.14, P = 0.04), external fixation placement (coef = 5.48, P = 0.04), and tourniquet time (coef = 0.06, P = 0.001) to be statistically significant. When placed in a multivariate model, BMI (coef = -0.31, P = 0.03) continued to be statistically significant as well as open injuries (coef = -12.62, P = 0.02), external fixation use (coef = 6.91, P = 0.003), and longer tourniquet times (coef = -0.064, P = 0.005). Once again, fixation type was not statistically significant when comparing function scores (coef = 0.70, P = 0.75). A list of the complications seen in the cohort is provided in Table 3.

On comparison of radiographic outcomes between DF and IF groups (Table 4), Weber C classification, fragment size, and the use of syndesmotic screws were determined to be statistically significant. Fractures that were classified as a Weber C were more likely to be fixed by DF than IF of the syndesmosis (D = 11 [28.2%], I = 6 [8.0%]; P = 0.02). Fractures with a larger posterior malleolus fragment size were more likely fixed with DR rather than IF (I = 17.8% ± 0.17, D = 25.2% ± 0.08; P = 0.002). There were also more cases that involved syndesmotic screws in the IF group versus the DF group (D = 11.1%, I = 52.6%; P < 0.001). In patients where time to union was available for analysis, DF had a shorter time to union on average than IF although not statistically significant (2.22 ± 0.69 vs. 6.17 ± 12.6, P = 0.23). In addition, in the indirect group, there were 2 screws that needed to be removed and 1 that broke. There was no statistically significant difference in time to union between both groups.

4. Discussion

The results from this study showed no difference in TP and function using the PROMIS outcome scores when comparing DF

TABLE 4
Comparison of Radiographic Outcomes for DF and IF Groups.

	Radiographic Outcomes		
	Direct	Indirect	P
Weber class A	1	4	0.02
Weber class B	27	65	
Weber class C	11	6	
Fragment size (%)	25.2 ± 0.08	17.8 ± 0.17	0.002
Time to union	2.22 ± 0.69	6.17 ± 12.6	0.23
Syndesmotic screws (%)	11.1	52.6	<0.001
1 screw	3	17	
2 screws	2	12	
3 screws	0	2	
4 screws	0	3	

and IF groups head-to-head. Further univariate and multivariate regression analyses also exhibited that fixation strategy did not significantly affect pain or function. However, overall cohort regression analysis did yield significantly increased risk of pain in patients with higher, BMI, complications, open injuries, and longer tourniquet time (smokers only in univariate analysis). BMI had a significant negative influence on TF scores while external fixation had a positive effect in regression analysis. Open injuries significantly negatively affected TF on multivariate analysis and approached significance on univariate. Age, diabetes, and complications had a significantly negative effect on function on univariate analysis. Increasing tourniquet time was significant for decreased function postoperatively on regression analysis. Fixation type did not show any significant difference in either univariate or multivariate regression analysis.

The pain outcome evaluated by PROMIS scores demonstrated BMI, complications, open injuries, and longer tourniquet times to have increased pain scores on univariate and multivariate analysis while tobacco use increased pain on univariate analysis. Tobacco use decreases the blood flow through its effect on the vascular anatomy and thus the necessary nutrients needed to promote successful healing after orthopaedic trauma.^[12,13] The use of tobacco is also inversely correlated with physical activity, which poses an issue for limited motion at the joint leading to stiffness and pain in the joint.^[14] Studies show that populations with a higher BMI have baseline chronic pain which predisposes them to increased postoperative pain. Specifically, a study by Dong et al^[15] determined that 58% of people with a BMI ≥30 report chronic pain in their extremities and lower back. For higher pain outcomes associated with open fractures, studies show that coping with traumatic events that occur with open fractures results in higher pain ratings even with successful ORIF, leading to longer hospitalization time, delayed ambulation, noncompliance with physical therapy, and increased incidence of complications.^[16-18]

Interestingly, the results also demonstrated increasing tourniquet time leading to increased pain scores while decreasing the function rating during follow-up examination. Similar studies have shown that the use of a tourniquet increased postoperative swelling and pain while decreasing ROM in the ankle on 6-week follow-up.^[19] In addition, Kukreja et al noted that increased tourniquet time is positively correlated with greater opioid use in the perioperative period.^[20,21] The postoperative pain scores may also be higher because perioperative opioid consumption is correlated with hyperalgesia and increased opioid tolerance.^[22,23] Regarding TF, BMI and tourniquet time were significant for decreased function while external fixation was significant for increased function postoperatively on regression analysis. On

univariate analysis, increasing age, complications, and diabetes were significant for decreased function postoperatively. On multivariate analysis, open fractures were significant for decreased function postoperatively. In addition, diabetes has been confirmed as a risk factor for a higher incidence of delayed healing and nonunion in foot and ankle fractures, which leads to lower functional outcomes.^[24,25] Similarly, Vincent et al^[26] showed that obese patients had lower Functional Independence Measure ratings with a lower magnitude and a slower rate of functional improvement during rehabilitation after orthopaedic trauma. External fixation of the ankle improved TF outcomes which aligns with the literature showing that external fixation is beneficial for preventing both loss of reduction and skin necrosis that may be a concern with splinting or immediate ORIF.^[27] Liskutin et al^[28] expanded on this by focusing on the ability for the soft tissue to rest after injury and the restoration of anatomic alignment that comes with external fixation. Furthermore, direct fixation was achieved in large fracture fragments with decreased time to union in our study.

The primary limitation of this study is only examining the short-term outcomes of direct versus indirect fixation of the posterior malleolus in the setting of trimalleolar fractures. Given that this study is a retrospective review in nature, some selection bias could be present with all retrospective analyses. In addition, the relatively small cohort size further hinders obtaining statistical data and elevating the power of evidence present. However, this was the basis for using regression analysis to support the findings determined by the head-to-head comparison and to further delineate any additional risk factors that may adversely affect outcome. In addition, a post hoc power analysis confirmed that this study had limited power regarding the PROMIS score comparison. Reaching appropriate power in a retrospective study of this nature is difficult, and we hope to use these data as an a priori power analysis for a prospective study with sufficient power. However, this was a contributing factor to running a regression analysis, which returned a valid F test and supports our findings.

5. Conclusion

This study has concluded that there is no difference in PROMIS scores for TF and TP when evaluating patients who have undergone ORIF of trimalleolar ankle fractures with direct versus indirect fixation of the posterior malleolus. Therefore, surgeons should rely on overall syndesmotic and tibiofibular joint stability for operative decision planning on whether to perform DF or IF of the posterior malleolus fragment. Future consideration for a randomized control study with groups comparing direct versus indirect fixation is needed to evaluate for superiority in outcomes for patients.

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