EC ORTHOPAEDICS
Research Article

Dual Plating Technique: Outcome Comparisons in Complex Ankle Fractures and Concurrent Complex Comorbidities

J Joseph Anderson[1]*, Anthony M Chesser[2], Devin S Bland[3], Loren Spencer[4], Devin Wahlen[5], Adebola T Adeleke[6], G Parker Peresko[7], Riley Rampton[8], Jacob M Jones[9], Geoffrey Cady[10] and Brooke Lynn Anderson[11]

[1]Surgeon and Partner at New Mexico Bone and Joint Institute Alamogordo, New Mexico, Fellowship Director at American Foundation of Lower Extremity Surgery and Research, USA

[2]Surgeon at Private Practice at ORA Orthopedics Moline, IL, USA

[3]Surgeon at Private Practice at Prestige Medical Care Phoenix, AZ, USA

[4]Surgeon and Partner at New Mexico Bone and Joint institute Alamogordo, NM, USA

[5]Surgeon at Private Practice at Eastern New Mexico Foot and Ankle Clovis, NM, USA

[6]Surgeon at Private Practice at Orthopedic Associates Middletown, CT, USA

[7]Surgeon at Arbor Health Hospital Morton, WA, USA

[8]Surgeon at Private Practice at Foot and Ankle Center Cache Valley, UT, USA

[9]Fellow at The American Foundation of Lower Extremity Surgery and Research, Alamogordo, NM, USA

[10]Surgeon at Private Practice at Gateway Foot and Ankle, Jefferson Hills, PA, USA

[11]Undergraduate at Northern Arizona University Flagstaff, AZ, USA

***Corresponding Author:** J Joseph Anderson, Surgeon and Partner at New Mexico Bone and Joint Institute Alamogordo, New Mexico, Fellowship Director at American Foundation of Lower Extremity Surgery and Research, USA.

Received: November 24, 2025; **Published:** December 30, 2025

Abstract

Ankle fractures are a common orthopedic injury which often require open reduction internal fixation (ORIF) in order to decrease the risk of posttraumatic arthritis. There are certain instances when more rigid fixation is needed i.e. osteopenia, neuropathy, and obesity. Dual/orthogonal plating of the fibula has been shown to be a promising adjunct in previous studies. The authors report on 181 dual plated fibulas and their postoperative outcomes vs standard single plating of the fibula. One thousand four hundred seventy-seven bimalleolar and trimalleolar ankle fractures were identified for this study. Retrospective chart review was performed for obesity, osteopenia, as well as neuropathy. Of the 1477 ankle fractures, 611 (41.37%) patients qualified for the study, 181 (29.62%) dual plate and 430 (70.38%) single plate constructs. In these records the areas that were compared were the following: dehiscence, failure of hardware fixation, loss of mortise length, height or width, loss of fibular length, catastrophic hardware failure, mal-unions, non-unions, and peroneal tendonitis. There were statistically significant P values when comparing single plate vs dual plating of the fibula in these areas: hardware failure (0.007), revisional surgery (0.007), hardware removal (0.034), Loss of fibula length (0.005), Loss of Mortise width (0.010), non-union/malunion (0.002), in the single plate group. Peroneal tendonitis, and postoperative cellulitis were not significant (0.10) and (0.94) respectively in either group. Single-plate fixation is significantly associated with increased post-operative complications in a population of patients with and without morbid obesity, osteoporosis, and/or neuropathy.

Keywords: *Anti-Glide; Morbidly Obese; Neuropathic; Orthogonal; Osteoporosis*

Level of Clinical Evidence:

- Therapeutic.
- Level 3-Retrospective comparative study.

Introduction

Ankle fractures are one of the most common fractures in the human body. The incidence of ankle fractures was 187 per 100,000 (.00187%) people in one study [1]. Although many times we think of these as simple fractures with low complexity, the reality is that many ankle fractures have a high-associated complication rate. Comorbidities such as diabetes, neuropathy, morbid obesity, and geriatric ankle fractures, or even non-geriatric ankle fractures with osteoporotic bone, play a significant role in the complication rates of ankle fracture fixation (Figure 1). While we realize the ankle fracture basics of reestablishing width of the ankle mortise, height of the tibial plateau, and length of the fibula and medial malleolus [2], many times we fail to appreciate the significant underlying pathology in which makes an ankle fracture so severe.

Figure 1: *Morbidly obese patient with ankle fracture.*

Although high-energy trauma is often seen with ankle fractures, many of these fractures are sustained with relatively low energy and significant rotational and translational forces. Combining even the lowest energy mechanisms with soft bone, neuropathic bone and/or morbid obesity can relate to a significant complication rate. When comparing a patient with a moderate body mass index (BMI) to a patient with a morbidly obese BMI complication rates can double and, with neuropathic diabetes, the need for revision surgery can be up to 5 times greater [3-6].

To state the obvious, it does not make sense that one would use the same fracture construct for a patient weighing 400 pounds or one with soft bone or neuropathic bone as one would use for a healthy 25-year-old with hard bone stock with a relatively low complex fracture (Figure 2 and 3). Given the significant complication rates and after the authors have seen failures of various fracture constructs, many times on revision fractures and also revising the work of other surgeons, the double-plate or orthogonal-type fracture fixation construct was utilized. The orthogonal construct biomechanically holds significant optimal advantage.

Figure 2: *Complex osteoporotic fracture in neuropathic patient.*

Figure 3: *Osteoporotic fracture.*

Dual plating has been described in multiple areas of the literature, for both biomechanical stability and for its role in multiple fracture-pattern types throughout the body [7-18]. Although dual plating has been described in a multitude of medical journals and papers and in a multitude of areas, it has never been significantly looked at with a large fracture population and specifically related to morbid obesity, known osteoporotic bone, and patients with neuropathy as complicating factors.

It is the authors' belief that, while one sacrifices some soft tissue-periosteal preservation by using dual plating, one gains significant rigidity which in turn, reduces complication rates for at risk population.

Methods

After obtaining institutional review board approval the authors retrospectively evaluated fractures from 2003, which presented from multiple facilities and institutions, to January of 2016. The authors subsequently isolated those patients, which could be found upon follow-up, those patients that had standard single plate fixation with interfragmentary screw fixation and neutralization either laterally or posterolaterally, with or without medial ligamentous deltoid repair versus medial malleolar fixation. On trimalleolar fractures, patients were not isolated or segregated whether or not they had syndesmotic fixation. If patients had significant trimalleolar component of the posterior tibia, they were excluded. We included 1,477 bimalleolar and trimalleolar fractures (470 trimalleolar and 1,007 bimalleolar fracture equivalents).

The charts were reviewed for the following: Obesity was defined as a BMI of greater than 30 (kg/m^2). Osteoporosis was defined as a bone mineral density study or DEXA scan within twelve months of the surgery that showed osteoporosis as defined by the World Health Organization criteria, or neuropathy as defined by loss of protective threshold sensation via 5.07 monofilament wire, regardless of the causes, such as hereditary sensory neuropathy, idiopathic neuropathy, or diabetic neuropathy [19].

Of the 1477 ankle fractures 611 patients which fell into the inclusion criteria for having significant comorbidities of neuropathy, osteoporosis or obesity. Of these included fractures, we determined that 291 met the criteria of having obesity as defined by a BMI greater than 30 [20].

Of the 611 patients, it was recorded whether or not they had complications with single-plate fixation such as dehiscence, failure of hardware fixation, loss of mortise length, height or width, or loss of fibular length, and even catastrophic hardware failure. Other complications include wound and bone healing or re-injury to or breakage of the same bone. Mal-unions, non-unions, and peroneal tendonitis were also recorded in each of the groups.

The patient's pre- and post-operative radiographs were also evaluated, and all subsequent radiographs for over the next 12 months minimum. Radiographs and radiological information were used to evaluate the complexity of the fracture, syndesmotic disruption, and to group the patients into bimalleolar or trimalleolar fracture groups, according to the AO criteria and the Lauge-Hansen classification for ankle fractures. All open fractures were excluded. All fractures that were lost to follow-up were also excluded.

All analyses began with assessment of the normality of the data using the Kolmogorov-Smirnov test. Continuous variables were reported as mean ± standard deviation and categorical data as counts and percentages. Non-normally distributed data were reported as median with interquartile range (IQR). Continuous demographic and clinical variables were compared by the independent samples t-test or Mann-Whitney U test, as appropriate. All cost data was compared using the Mann-Whitney U test. The chi-square test or Fisher's exact was used to determine the association between type of plate fixation (double-plate versus single-plate) and categorical data. Patients with BMI >30 in the double-plate fixation and single-plate groups were analyzed separately for demographics, comorbidities, post-operative complications and procedure-related costs. In all analyses, a value of $p<.05$ on two-tailed testing was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics, version 24.0 (IBM Corp. Armonk, NY).

Surgical technique

Patients, for the standard surgical technique, were placed in the supine position with a lateral and ipsilateral bump as indicated. The appropriate fracture fixation construct was utilized and a standard AO reduction technique was obtained with interfragmentary compression as long as it could be achieved. For the ligamentous deltoid disruption, these were opened and repaired directly. For bimalleolar ankle fractures in which the medial malleolus was disrupted, it was fixated using standard AO reduction technique with lagged or partially threaded screws on the medial malleolus. For vertical sheer fractures of the medial malleolus, interfragmentary compression was used but also a buttress anti-glide type medial malleolar plate was used if indicated by fracture pattern type. The fibula, if could be ascertained, an interfragmentary screw fixation was used to fixate it with a slightly anterior and lateral neutralization plate, utilizing standard AO reduction techniques to re-establish length, height and width of the mortis. For the trimalleolar variant fractures with syndesmosis disruption or Weber C type fracture, standard fixation with one to two syndesmotic screws were placed with the standard positioning and alignment while the syndesmotic screws were used to fixate. Any tight rope or zip-tight type suture anchor syndesmotic fixation devices were excluded from this data collection and paper.

All patients who had catastrophic failures of their hardware after the syndesmotic screws were removed were also excluded from this study, if syndesmotic widening was the only complication seen.

The surgical technique for the double-plate fixation was similar with slight variation for fractural pattern (Figure 4). Patients were placed in supine position with a lateral and ipsilateral bump as indicated. The appropriate fracture fixation construct was utilized and a standard AO reduction technique was obtained with interfragmentary compression as long as it could be achieved. For the ligamentous deltoid disruption, these were opened and repaired directly. For bimalleolar ankle fractures in which the medial malleolus was disrupted, it was fixated using standard AO reduction technique with lagged or partially threaded screws on the medial malleolus.

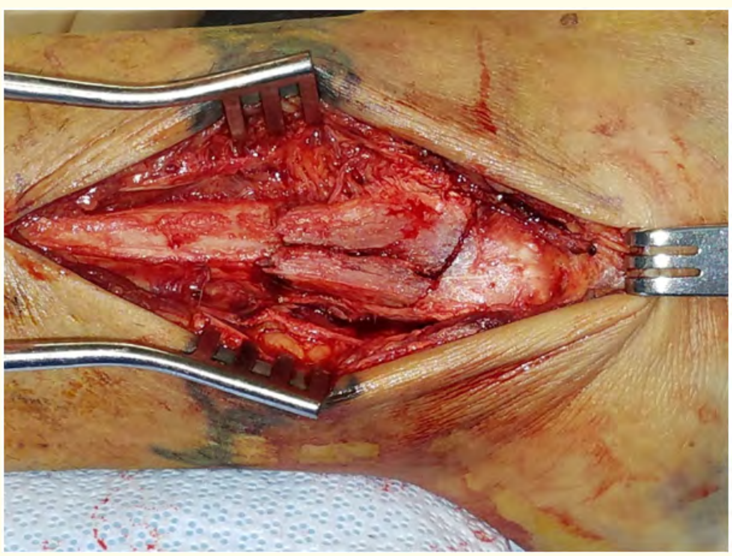

Figure 4: *Intra op of comminuted fracture.*

For vertical sheer fractures of the medial malleolus, interfragmentary compression was used but also an anti-glide buttress-type medial malleolar plate was used if indicated by fracture pattern type. An interfragmentary screw fixation was used to fixate the fibula with a slightly anterior and lateral neutralization plate, utilizing standard AO reduction techniques to re-establish length, height, and width of the mortis. For the trimalleolar variant fractures with syndesmosis disruption or Weber C type fracture, standard fixation with one to two syndesmotic screws were placed with the standard positioning and alignment while the syndesmotic screws were used to fixate. On the fibula, once the length, height and width had been restored, a posterolateral antiglide type plate was used and fixated using standard AO reduction techniques. The anti-glide buttress-type plate was especially important and utilized with multiple comminuted segmental lost fibula fractures and also in those with which would not entertain interfragmentary screw fixation (Figure 5 and 6).

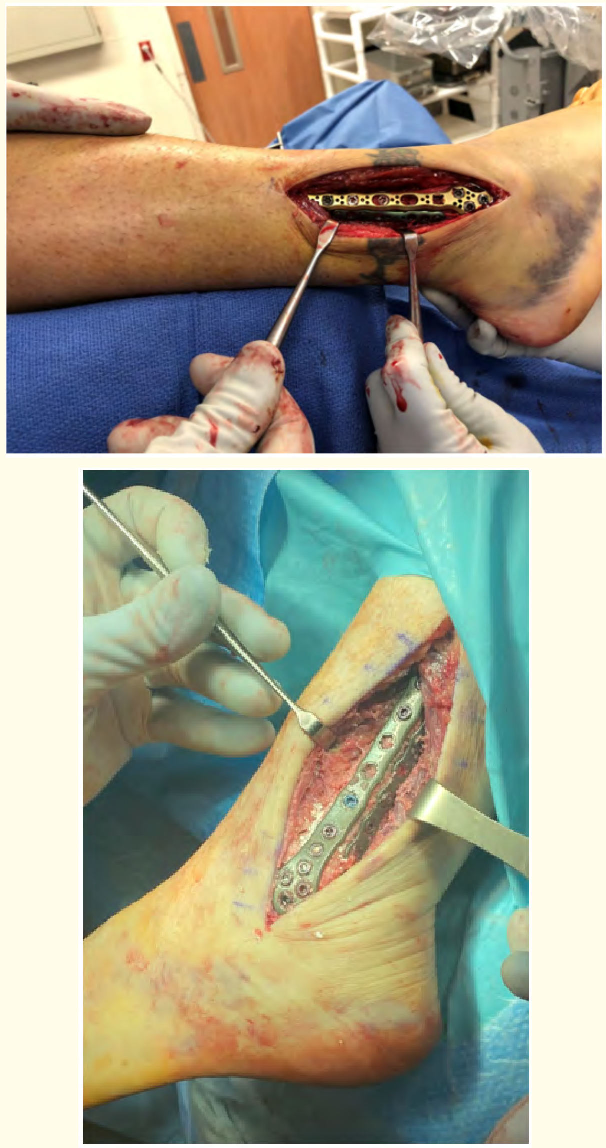

Figure 5a and 5b: *Intra op photos of double plate technique.*

Figure 6a and 6b: *Various radiographs of double plate technique.*

Results

The study population consisted of 611 (N = 611) patients with ankle fractures with bimalleolar and trimalleolar variants who were treated between January 2003 and January 2016. This study is a single-center retrospective chart review of these patients and their outcomes.

The median age of the 611 (N = 611) patients at baseline was 61 (IQR = 19) years, and 62.7% of the patients were female. Concomitant comorbidities included morbid obesity (BMI (kg/m^2) >30) (47.6%), diabetes mellitus (or other neuropathy) (47.3%), and osteoporosis (43.4%) on a Dexa scan within the 36 months preceding treatment of ankle fractures with double-plate or single-plate fixation. In the study population, median BMI (kg/m^2) was 29.1 (IQR = 6.9). Median age did not differ significantly between double-plate fixation (n = 87) (61 (IQR = 21) years) and single-plate fixation (n = 204) groups (62 (IQR = 19) years) (p = .77). Gender was not significantly associated with group (p = .41). Among those patients that underwent double-plate fixation (n = 181), 65.2% were female and 34.8% were male versus proportions of 61.6% female and 38.4% male in the single-plate fixation group (n = 430).

Sixty-two percent of patients had only one comorbidity; 38% had two comorbidities. The number of comorbidities was not significantly associated with group (p = .43). Sixty-four percent of patients in the double-plate fixation group had only 1 comorbidity versus 60.7% in the single-plate fixation group. Thirty-six percent of patients in the double-plate fixation group had two comorbidities versus 39.3% of patients in the single-plate fixation group (Table 1).

Variable	**Double-Plate Fixation (n = 181)**	**Single-Plate Fixation (n = 430)**	**P value**
Median Age, years	61 (IQR, 21.0)	62 (IQR, 19)	.77
Sex			.41
Female	118 (65.2)	265 (61.6)	
Male	63 (34.8)	165 (38.4)	
Comorbidities			
BMI (kg/m^2)			
Median (IQR)	29.4 (IQR, 7.3))	29.1 (IQR, 6.5)	.74
BMI (kg/m^2)>30 (Morbid obesity)	34.3 (IQR, 5.0) (n = 87)	33.8 (IQR, 7.0) (n = 204)	.35
BMI<30	26.9 (IQR, 4.0) (n = 94)	27.4 (IQR, 3.3) (n = 226)	.80
Osteoporosis on Dexa scan within 36 months of treatment of ankle fracture	73 (40.3)	192 (44.7)	.33
Diabetes mellitus or another neuropathy	86 (47.5)	203 (47.2)	.95
Number of Comorbidities			.43
Only one comorbidity	116 (64.1)	261 (60.7)	
Two comorbidities	65 (35.9)	169 (39.3)	

***Table 1**: Demographic and baseline characteristics of the study population with complex ankle fractures and concurrent complex comorbidities (N = 611).*

Non-normally distributed data are reported as median with interquartile range; categorical data are reported as count and percentage.

Fixation with a syndesmotic screw was not significantly associated with group (p = .48) (Table 2).

Variable	Double-Plate Fixation (n = 181)	Single-Plate Fixation (n = 430)	P value
Type of Fracture			.01*
Bimalleolar	125 (69.1)	339 (78.8)	
Trimalleolar	56 (30.9)	91 (21.2)	
Syndesmotic Screw	138 (76.2)	316 (73.5)	.48

Table 2: *Clinical data of the study population (N = 611).*

**Statistically significant.*

Categorical data are reported as count and percentage.

Overall (N = 611), the proportion of patients with hardware failure was 3.8%. Neither peroneal tendonitis nor cellulitis were significantly associated with group (p = .10 and p = .94, respectively). Hardware failure (p = .007), revision of surgery (p = .007), hardware removal (p = .034), loss of fibula length (p = .005), loss of mortise width (p = .010) and nonunion/malunion (p = .002) all were statistically significant (Table 3).

Variable	Double-Plate Fixation (n = 181)	Single-Plate Fixation (n = 430)	P value
Hardware Failure	1 (0.6)	22 (5.1)	.007*
Revision Surgery	1 (0.6)	22 (5.1)	.007*
Hardware Removal	25 (13.8)	91 (21.2)	.034*
Peroneal Tendonitis	11 (6.1)	44 (10.2)	.10
Loss of Fibula Length	1 (0.6)	23 (5.3)	.005*
Loss of Mortise Width	2 (1.1)	25 (5.8)	.010*
Cellulitis	24 (13.3)	58 (13.5)	.94
Non-Union/Malunion	0	23 (5.3)	.002*

Table 3: *Post-operative complications (N = 611).*

**Statistically significant.*

Categorical data are reported as count and percentage.

The median cost of a second surgery did not differ significantly between double-plate fixation (n = 181) ($9,871 (range 5,180 to 14,562)) versus single-plate fixation (n = 430) groups ($6,908 (range 1,777 to 34,866)) (p = .91) (Table 4).

Variable	Double-Plate Fixation (n = 181)	Single-Plate Fixation (n = 430)	P value
Initial Hardware Cost, dollars			
Mean	3,583.4 ± 943.1	2,669.4 ± 537.6	
Median	3,323 (IQR, 1,063) (Range = 2278 – 5899)	2,633 (IQR, 734) (Range = 1389 – 4231)	.001*
Had Second Surgery	2 (1.1)	31 (7.2)	.002*
Second Surgery Cost, dollars			

Mean	9,871.0 ± 6,634.1	10,709.2 ± 8,572.0	.91
Median	9,871 (No IQR) (Range = 5,180 - 14,562)	6,908 (IQR, 11,419) (Range = 1,777 - 34,866)	.
Total Cost, dollars	$3,432	$3,130	

***Table 4**: Cost data (N = 611).*

**Statistically significant.*

Non-normally distributed data are reported as median with interquartile range; categorical data are reported as count and percentage.

*Total Cost = Median Hardware Cost + Median Second Surgery Cost * [Rate of Second Surgery].*

*Total cost was computed for the double-plate fixation group as: $3,323 + 1.1% * $9,871 = $3,432. Total cost was computed for the single-plate fixation group as: $2,633 + 7.2% * 6,908 = $3,130.*

Of the 611 (N = 611) patients in the study, 291 (47.6%) had BMI (kg/m^2) >30. Of the 291 (n = 291) patients with BMI (kg/m^2) >30, a higher proportion were in the single-plate fixation group (70.1%) than the double-plate fixation group (29.9%) (Table 5).

Variable	**Double-Plate Fixation with BMI (kg/m^2) >30 (n = 87)**	**Single-Plate Fixation with BMI (kg/m^2) >30 (n = 204)**	**P value**
Age, years			
Median (range)	49 (IQR, 17)	58 (IQR, 16)	.32
Sex			.57
Female	53 (60.9)	117 (57.4)	
Male	34 (39.1)	87 (42.6)	
Comorbidities			
Morbid obesity (BMI kg/m^2) >30	87 (100)	204 (100)	
Osteoporosis on Dexa scan within 36 months of treatment of ankle fracture	9 (10.3)	21 (10.3)	.99
Diabetes mellitus or another neuropathy	54 (62.1)	144 (70.6)	.15
Number of comorbidities			.11
Only 1 comorbidity	24 (27.6)	39 (19.1)	
Two comorbidities	63 (72.4)	165 (80.9)	

***Table 5:** Demographic and baseline characteristics of the study population with BMI (kg/m^2) >30 and complex ankle fractures and concurrent complex comorbidities (N = 291).*

Non-normally distributed data are reported as median with interquartile range; categorical data are reported as count and percentage.

The median age, at baseline, of the 291 (N = 291) patients with BMI (kg/m^2) >30 was 49 years (IQR = 17), and 58.4% of the patients were female. None of the individual comorbidities differed significantly between groups. In patients with median BMI (kg/m^2) >30 (defining morbid obesity), median BMI (kg/m^2) was 34.3 (IQR = 5.0) in the double-plate fixation group (n = 87) compared with 33.8 (IQR = 7.0) in the single-plate fixation group (n = 204) (p = .35). The proportions of patients with osteoporosis on a Dexa scan within 36 months preceding treatment of ankle fractures with either single-plate or double-plate fixation were similar (p = .99): 10.3% in the double-plate fixation group versus 10.3% in the single-plate fixation group. The proportion of patients with diabetes mellitus (or other neuropathy) was slightly higher in the single-plate fixation group compared with the double-plate fixation group (70.6% versus 62.1%), however, this difference was not statistically significant (p = .15) (Table 5).

Number of comorbidities was not significantly associated between the groups (p = .11). Twenty-eight percent of patients in the double-plate fixation group (n = 87) had only 1 (.011%) comorbidity versus 19.1% in the single-plate fixation group (n = 204). Seventy-two percent of patients in the double-plate fixation group had two comorbidities versus 80.9% of patients in the single-plate fixation group (Table 5).

Type of ankle fracture was not significantly associated with group (p = .08). Bimalleolar fractures occurred in 56.3% of patients in the double-plate fixation group (n = 87) compared with 67.2% of patients in the single-plate fixation group (n = 204); trimalleolar fractures occurred in 43.7% of patients in the double-plate fixation group compared with 32.8% of patients in the single-plate fixation group. Fixation with a syndesmotic screw was not significantly associated with group (p = .45) (Table 6).

Variable	Double-Plate Fixation (n = 87)	Single-Plate Fixation (n = 204)	P value
Type of Fracture			.08
Bimalleolar	49 (56.3)	139 (67.2)	
Trimalleolar	38 (43.7)	67 (67.2)	
Syndesmotic Screw	72 (82.8)	161 (78.9)	.45

Table 6: *Clinical data of the study population with BMI (kg/m^2) >30 (N = 291).*

Categorical data are reported as count and percentage.

The overall hardware failure rate in the 291 (N = 291) patients with BMI (kg/m^2) was 5.2%. Single-plate fixation (n = 204), compared with double-plate fixation (n = 87), was significantly associated with increased post-operative complications, including: hardware failure (7.4% vs. 0, p = .007), revision surgery (7.4% vs. 0, p = .007), and hardware removal (35.8% vs. 18.4%, $X^2(1) = 8.7$, p = .003). Patients who received single-plate fixation were nearly 2.5 times more likely to have hardware removal than patients who received double-plate fixation (95% CI, 1.3, 4.57) (Table 7).

Variable	Double-Plate Fixation with BMI (kg/m^2) >30 (n = 87)	Single-Plate Fixation with BMI (kg/m^2) >30 (n = 204)	P value
Hardware Failure	0	15 (7.4)	.009*
Revision Surgery	0	15 (7.4)	.009*
Hardware Removal	16 (18.4)	73 (35.8)	.003*
Peroneal Tendonitis	10 (11.5)	36 (17.6)	.19
Loss of Fibula Length	1 (1.1)	15 (7.4)	.046*
Loss of Mortise Width	1 (1.1)	17 (18.3)	.02*
Cellulitis	19 (21.8)	52 (25.5)	.51
Non-Union/Malunion	0	14 (6.9)	.01*

Table 7*: Post-operative complications in double-plate fixation versus single-plate fixation patients with BMI (kg/m^2) >30 (N = 291).*

**Statistically significant.*

Categorical data are reported as count and percentage.

Significantly higher proportions of post-operative complications were also found in single-plate fixation (n = 204), compared with double-plate fixation (n = 87), loss of fibula length (7.4% vs. 1.1%, p = .046), loss of mortise width (8.3% vs. 1.1%, $X^2(1) = 5.4$, p = .02) and non-union/malunion (6.9% vs. 0, p = .01) (Table 7).

Neither peroneal tendonitis nor cellulitis were significantly associated with double-plate or single-plate fixation groups for BMI (kg/m^2) >30 (p = .51 and p = .19, respectively) (Table 7).

Median long-term costs, including cost of failures and replacements, was $3,318.47 in the single-plate fixation group with BMI (kg/m^2) >30, however, long-term cost in the double-plate group could not be determined since only 1 patient underwent a second surgery (Table 8).

Variable	Double-Plate Fixation with BMI (kg/m^2) >30 (n = 87)	Single-Plate Fixation with BMI (kg/m^2) >30 (n = 204)	P value
Hardware Cost, dollars			
Mean	3,733.4 ± 1060.7	2,652.1 ± 572.8	
Median	3,367 (IQR, 1084.0) (Range, 2,278 – 5,899)	2,631 (IQR, 776.0) (Range, 1,389 – 4,231)	.001*
Had Second Surgery	1 (1.1)	20 (9.8)	.009*
Second Surgery Cost, dollars			
Mean	Constant, since only 1 pt in the double-plate fixation group had surgery	11,201.4 ± 8,867.6	.
Median	Constant, since only 1 pt in the double-plate fixation group had surgery	7,015.0 (IQR, 1,2691) (Range, 1,777 – 34,866)	Could not be calculated.
Total Cost, dollars	Undetermined	$3,318.47	

Table 8: *Cost data of patients with BMI (kg/m^2) >30 (N = 291).*

**Statistically significant.*

Non-normally distributed data are reported as median with interquartile range; categorical data are reported as count and percentage.

*Total Cost = Median Hardware Cost + Median Second Surgery Cost * [Rate of Second Surgery].*

*Total cost was computed for the single--plate fixation group as: $2,631 + 9.8% * $687.47 = $3,318.47.*

Discussion

Complication rates following ORIF of ankle fractures are well documented in the literature. Several studies have looked into certain predictors to assess adverse events for certain patient populations. SooHoo., *et al.* [21] article finds complicated diabetes, open injuries, and peripheral vascular disease were strong factors that predicted complications post operatively. Another study showed risk factors such as age >65 years, obesity, diabetes, and ASA scores of >2, functional status are all predictive factors for all postoperative complications [22]. A similar article also concluded that diabetes and patients with increased ASA scores had increased risk for postoperative readmission and morbidities [23]. This article now shows that single plate fixation is associated with a higher post-operative complication rates with patients with obesity and osteoporosis.

Catanzariti and Mendicino [24] review on diabetic neuropathic fracture management had several articles depicting the effects of diabetes and its effects on fracture complications. They cited Reddy., *et al*. [25] and their study on the integrity of bones in rat models with induced diabetes. This group found a 37% reduction in maximum load capability. 25% less deformation at maximum load and 38% increase in bending stiffness. They concluded with their study stating that diabetes mellitus could predispose patients to bony problems [25]. Patients with long standing diabetes are at risk for fracture and Ivers., *et al*. [26] in their study also found that patients who were diabetic for >10 years, had retinopathy and were insulin dependent had statistically significant risk of fractures. One of the more debilitating conditions for neuropathic patients is the compounding complication of a Charcot process after fracture [24]. Lovy., *et al*. [27] in their head to head study on non-operative vs operative treatment of ankle fractures in diabetics showed a 21-fold increased odd of complication as compared with operative treatment. Concerning yet is the 7 Charcot joints (35%) which developed with non-operative patients. They concluded that non-operative treatment of diabetic ankle fractures was associated with unacceptably high levels when compared with operative treatments [27].

While the census is leading to fixating diabetic ankle fractures these patients' comorbidities are not benign. Wukich., *et al*. [28] in their study showed an infection rate for diabetic ankle fractures ranging from 17%- 50% with an amputation rate of 4-17% in the literature [28-31]. Vaudreuil., *et al*. [32] in their study on limb salvage after failed initial operative management of bimaleolar ankle fractures had a 17.7% rate of limb loss, which was similar to Wukich., *et al*. [28] findings. No patient in this current study went on to limb loss due to complications from surgery.

Other studies have looked at osteoporotic bone and its complication rates with elderly neuropathic patients [33]. Non-operative treatment in elderly osteoporotic patients have a non-union rate between 48% [34] and 73% [35-37] with a malunion rate between 36% [35] and 61% [37]. ORIF does decrease nonunion as well as malunion rates, but the incidence of wound complications ranges from 9% to 23% [38].

Literature is limited and mixed with the discussion of obesity and its effects on ankle fractures. Some studies comment on obesity and its protective effects due to increased soft tissue coverage [39]. Other articles state there is no long-term difference with patients with a BMI of greater than 30 kg/m^2 who had unstable ankle fractures [40].

They also looked at morbidly obese patients and did not find any correlation with poor outcome and increased complications [41]. In Bostman's [41] article, there was statically significance in patients with obesity with ankle fractures and these patients require prolonged periods of non-weightbearing and stronger internal fixation techniques. Spaine and Bollen [42] in their study showed that patients with a higher BMI had a greater chance for a more complex dislocated fracture of the ankle, however outcomes were not recorded. One article states that patients with a BMI of greater than 30 kg/m^2 have a greater chance of having a Weber C type ankle fracture [43]. Deakin., *et al*. [44] in their study not only discussed the pathophysiology in bariatric patients but the need for additional fixation, appropriate instrumentation, and higher risk of morbidities and mortalities due to co-morbidities. These articles reinforce that operative care should be performed due to non-operative problems (malunion/nonunion, Charcot etc). Dual plating can be used as an adjunct if the surgeon is concerned with the patient's habitus or co morbidities.

Other areas which were not addressed specifically in this paper were the time of immobilization, the amount of physical therapy, the return to range of motion and certainly isolating the particular types of fracture into specific fracture pattern types may certainly have stratified each of the complications into a particular group, had this been looked at. Also, the varying types of locking and non-locking screws, the types and varieties of plate fixation were not controlled for, nor were they specifically recorded, only whether or not they had a double-plate fixation technique utilized on the fibula.

It could be argued that perhaps a different construct of locking and non-locking screws, a different plate, or additional syndesmotic fixation may have resulted in as stable of a construct. However, this may be theorized, it certainly was not suggested by this study.

Our study has several limitations. The most important limitation derives from its design as a retrospective medical chart review and the bias introduced in the selection and assignment of patients to the double-plate or single-plate fixation groups. Physicians may have been influenced in their choice of procedure (double-plate versus single-plate fixation) by prior knowledge of the patients' comorbidities. This propensity-to-treat bias results in the reporting of associations not necessarily related to procedure type or comorbidities independently but possibly the result of clinical decisions. Cost data should have included facility fee, bone setting, casts, x-rays, CTs, MRIs, anesthesia and/or any prescription drugs required during the ankle fracture treatment. No patient follow-up was done in order to determine the longer-term outcome of the procedures. Finally, this is a study carried out in a single hospital within a university setting associated with a foot and ankle institute, which lessens generalizability of results.

The authors feel as though this study's results show distinctly that there is a statistical advantage to double-plate fixation in patients which have a significant comorbidity of morbid obesity, significant osteoporosis, or significant neuropathy in which a complex fracture pattern is also concurrent [45-47].

Conclusion

The authors conclude that in patients with high-risk comorbidities such as osteoporosis, morbid obesity and peripheral neuropathy, double plate fixation has a statistically significant advantage as compared to single-plate fixation when looking specifically at post-operative complication rates within the first twelve months following injury.

Single-plate fixation is significantly associated with increased post-operative complications in a population of patients with and without morbid obesity, osteoporosis, and/or neuropathy. In the total study population, initial median hardware cost was significantly higher in the double-plate fixation group compared with the single-plate fixation group, but no statistically significant difference between groups was found in long-term total cost when failure and replacement costs were taken into consideration.

Further studies are needed to look specifically at the financial implications, especially in those that require revision surgery due to hardware failure, the legal implications and ramifications of hardware failure may also be appreciated and further ramifications such as loss of work, time immobilized, and secondary psychological effects of multiple revision surgeries and the associated complications of anesthesia and revision surgeries in those patients.

Further studies are also needed to look at the long-term ramifications such as traumatic arthrosis, return to duty, previous weightbearing status, and also return to level of activity.

Lastly, as reported in clinical results in lack of dehiscence compared to single plate technique, the bulkiness and the sacrifice of increased periosteal and soft tissue stripping is statistically negated by the more stable construct of a double-plate fixation. The lack of peroneal tendonitis, or at least the equivalent amount of peroneal tendonitis in both groups, would suggest that posterior anti-glide plate typically does not cause this secondary complication as was more previously thought to be a higher instant.

Excellent results have been seen with double-plate fixation and this should remain a viable option in patients with significant comorbidities and those treating complex ankle fractures in these higher risk groups especially in the obese, osteoporotic, and neuropathic.

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