Risk Factors for Reoperation Following Operative Fixation of Distal Femur Fractures: A Report of 73 Consecutive Cases

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ABSTRACT

Introduction: Various factors including patient demographics, fracture types, and fixation methods can affect the outcomes of distal femur fractures. This study aimed to analyze the risk factors for reoperation after operative fixation of these fractures.

Methods: This was an institional review board (IRB) approved retrospective study of extra-articuilar, partial articular, and complete articular distal femur fractures treated with operative fixation at a Level I trauma center between 2008 and 2018. The study included a consecutive series of adult patients operatively treated for a distal femur fracture. The primary outcome was reoperation rate due to infection, non-union, or implant failure. Periprosthetic distal femur fractures were excluded. Statistical analysis used logistic regression.

Results: This study included 73 patients; 70 (96.0%) were closed fractures, and 3 were open. The average age at time of fracture was 61.6 years ± 18.2 years old. Fixation methods included external fixation (3 out of 73), intramedullary nailing (8 out of 73), and locking plates (62 out of 73). Of the 73 cases, 71 cases required nail alone, while two cases required nail and plate combination. The median follow-up time after operation was 14.2 months (InterQuartile Range, (IQR): 3.0, 17.2). Infection was reported in 6 out of 73 (8.0%) patients; reoperations occurred in 11 out of 73 (15.0%) patients. Age at presentation was the only patient demographic to negatively impact the odds of reoperation (odds ratios (OR) = 0.96, 95.0%, confidence interval (CI): [0.92, 0.99]). Patiens who sustained motor vehicle accidents (MVA) were 4.6 times more likely to require reoperation when compared to falls as the mechanism of injury (*P*-value = 0.032). Additionally, open fracture type was 13.6 times more likely to require reoperation as compared to the closed fracture type (*P*-value = 0.041). Using bone grafts decreased the risk of additional surgery as there was 80.0% less chance of requiring reoperation (OR = 0.2, 95.0% CI: [0.05, 0.77], *P*-value = 0.019). This was the only operational characteristic to impact the odds of reoperation.

Conclusion: Several risk factors may lead to reoperation following operative fixation of distal femur. This study found that age of presentation, mechanism of injury, type of fracture including Arbeitsgemeinschaft für Osteosynthesefragen, (AO)/Orthopedic Trauma Association, (OTA) classification and bone graft use can all impact the odds of reoperation. While some of these factors cannot be controlled, having a better understanding of the risk factors associated with reoperation of distal femur fractures can lead to better management of these fractures by orthopaedic surgeons.

Keywords: Reoperation; Open fractures; Femoral fractures; Distal femur fracture

INTRODUCTION

Distal femur fractures comprise 3.0% to 6.0% of all femoral fractures.[1] These injuries are challenging to manage surgically due to metaphyseal comminution, articular surface involvement, delayed union, and non-union.[2,3] Rates of non-union have been reported up to 6.0%.[3-5] High-energy trauma, including motor vehicle accidents (MVA), are responsible for a majority of the cases in the younger population, while low-energy mechanisms (e.g., falling from a standing position) are

common among the elderly population, especially in those with osteoporosis.[6-9] Open fractures of the distal femur are the most challenging. They are associated with severe soft-tissue damage, periosteal stripping, and increased risk of infection.[9] Different fixation methods have been used to treat these fractures, from the temporary placement of an external fixator to open reduction and internal fixation (ORIF) with fixed-angle blade plates, dynamic condylar screws (DCS), locking plates, intramedullary nails, or a combination of a plate and nail.[2,9]

Several factors can negatively affect the outcome of operative fixation. Risk factors include: patient characteristics such as patient's age, diet, and preexisting comorbidities (e.g., osteoporosis, diabetes, and tobacco/alcohol use). Other risk factors are related to the type of fracture (e.g., open vs closed) and the fixation method (e.g., locking plates, intramedullary nails) used.[3,5] Literature has shown that diabetes and open fractures are known to adversely affect fracture healing, lead to deep infections, and necessitate reoperation.[10-12] Other fixation characteristics such as plate-working length and number of screws have been evaluated biomechanically. [13,14] However, their clinical and operative impact has not been well clarified.[13,14]

This study aimed to determine the risk factors for reoperation following operative fixation of a distal femur fracture in a cohort studied over a 10-year period in a level-one trauma center..

METHODS

Inclusion Criteria and Data Collection

The study protocol was submitted and approved by the Institutional Review Board (IRB) at this institution. The study assigned an IRB number of E18106. This is a retrospective review of patient charts from a Level I trauma academic center. Charts from 2008 to 2018 were searched for operative fixation of distal femur fractures by the appropriate current procedureal terminology (CPT) and Internal Classification of Diseases-Version 10, ICD-10 codes. A preliminary search from the database yielded 456 patient charts. Patients included in this retrospective cohort study had to be ≥ 18 years of age, sustained distal femur fracture (e.g., intra-articular vs extra-articular and open vs closed), and opertaive treatment method (e.g., intramedullary nail, plates, external fixators). Patients under 18 years old and those with a periprosthetic distal femur fracture were excluded from the study. After applying the inclusion and exclusion criteria, 73 patient charts were included in the current analysis.

All the data collected from the patient charts and radiographs were stratified by fracture type (e.g., open and closed fracture). Other data collected included demographic information ((age, gender, comorbidities (e.g., diabetes, osteoporosis and other chronic medical conditions), tobacco/alcohol/drug use, mechanism of injury, Arbeitsgemeinschaft für Osteosynthesefragen, (AO)/Orthopedic Trauma Association (OTA) classification bone grafting attempts, fixation methods, other fixation characteristics (e.g., plate length)).

Outcome Measures

Primary outcome measures for this study were occurrence of infection or reoperation. Superficial infections were defined as infections that did not infiltrate the hardware and were managed with local wound care on an outpatient basis and/or oral antibiotics only. Reoperations were defined as adjunctive surgeries required for deep infection, delayed union, and non-union based on the operating surgeon's assessment. Deep infections required intravenous (IV) antibiotics with possible implant removal, or use of local antibiotic beads in addition to surgical intervention. Non-union was described as a failure of fracture union 6 months after surgical intervention. Implant failure was defined as non-union secondary to mechanical failure of fixation methods requiring implant replacement and surgical revision. Examples of mechanical failures of fixation methods include broken plates, nails, or screws.

Statistical analysis: Data analyses were carried out using STATA V.15. Data were presented as either mean and standard deviation (SD) or median and interquartile range to describe the quantitative variables from the patient demographics, fracture type, fixation methods, and operative outcomes. To describe the categorical variables, the authors calculated frequencies and proportions. The Student's T-test and Chi-squared test were used to assess differences in fracture type. In the case of violation of non-normal data, Mann-Whitney U or Kruskal-Wallis tests were used. The univariate logistic regression model was performed to assess the unadjusted risk of putative independent cofactors for reoperation. These estimates were reported as odds ratios (OR) and 95.0% confidence interval (CI). P-values of less than 0.05 were considered statistically significant.

RESULTS

Patient Characteristics

Overall, the average age of the patients at the time of fracture was 61.8 years ± 18.2 years old (range: 19 to 99). Females comprised 59.0% of the study subjects, and 41.0% were male. Of the 73 subjects, 18 had no comorbidities, 11 had only one comorbidity and 44 had more than one comorbidity. Current tobacco users made up 22.0% (16 out of 73) of the cohort at the time of evaluation. The majority of subjects denied drug use (96.0%) and alcohol use (84.0%). Data from the patient characteristics were also stratified by fracture type (Table 1). The median follow-up for the 73 cases was 6 months (3 months to 16.3 months). Although the follow-up time was longer in the open fracture group at 12.0 months (8.5 months to 38 months), no statistical significance was found between follow-up time and type of fracture (P = 0.16).

Table 1. Patient Characteristics

		Type of Fracture		
Factor	**Cohort**	**Close**	**Open**	***P*-value**
N	**73**	**70**	**3**	
Age (years), mean (SD)	61.6 (18.2)	61.8 (18.6)	57 (1)	0.66
Gender				
Female	43 (59.0%)	42 (60.0%)	1 (33.0%)	0.36
Male	30 (41.0%)	28 (40.0%)	2 (67.0%)	
Tobacco Use				
Current	16 (22.0%)	16 (23.0%)	0 (0.0%)	0.08
Never	29 (40.0%)	29 (41.0%)	0 (0.0%)	
No	28 (38.0%)	25 (36.0%)	3 (100.0%)	
Drug Use				
No	70 (96.0%)	67 (96.0%)	3 (100.0%)	0.71
Yes	3 (4.0%)	3 (4.0%)	0 (0.0%)	
Comorbidities				
None	18 (25.0%)	18 (26.0%)	0 (0.0%)	0.36
Only 1	11 (15.0%)	11 (16.0%)	0 (0.0%)	
More than 1	44 (60.0%)	41 (59.0%)	3 (100.0%)	
Alcohol Use				
No	61 (84.0%)	59 (84.0%)	2 (67.0%)	0.42
Yes	12 (16.0%)	11 (16.0%)	1 (33.0%)	

Data are presented as number and percentage or mean and standard deviation (SD). Student t or two-sided Chi-square test was used. Significance was set at a p-value less than 0.05.

Table 2. Fracture Characteristics

		Type of Fracture		
Factor	**Cohort**	**Close**	**Open**	***P*-value**
N	**73**	**70**	**3**	
Mechanism of Injury				
Fall	50 (68.0%)	50 (71.0%)	0 (0.0%)	<0.001
MVA	21 (29.0%)	19 (27.0%)	2 (67.0%)	
Twisting Injury	2 (3.0%)	1 (1.0%)	1 (33.0%)	
AO/OTA classification				
33-B1	1 (1.0%)	1 (1.0%)	0 (0.0%)	0.37
33-A1	20 (27.0%)	20 (29.0%)	0 (0.0%)	
33-A2	4 (5.0%)	4 (6.0%)	0 (0.0%)	
33-A3	3 (4.0%)	3 (4.0%)	0 (0.0%)	
33-B1	3 (4.0%)	2 (3.0%)	1 (33.0%)	
33-B2	4 (5.0%)	4 (6.0%)	0 (0.0%)	
33-C1	6 (8.0%)	6 (9.0%)	0 (0.0%)	
33-C2	12 (16.0%)	11 (16.0%)	1 (33.0%)	
33-C3	20 (27.0%)	19 (27.0%)	1 (33.0%)	

Data is presented as number and percentage. Two-sided Chi-square test was used. Significance was set at p-value less than 0.05. MVA: motor vehicle accident.

Fracture Characteristics

In total, 95.0% (70 out of 73) of included patients suffered from closed distal femur fractures while the remaining 4.0% (3 out of 73) had open distal femur fractures. The most common mechanism of injury was a fall (68.0%) followed by MVAs and twisting injuries. Fractures were also categorized by the AO/OTA classification system.[15] A majority of the fractures were 33-A1 ((i.e., simple extra-articular, avulsion fractures) and 33-C3 (i.e., multifragmentary complete articular fractures (Table 2)).

Fixation Characteristics

Overall, external fixation, intramedullary nails, and ORIF with plates were used in 4.0%, 11.0%, and 85.0% of cases, respectively. The type of plate implant used was at the operating surgeon's discretion. When stratifying by type of fracture, only external fixation and plates were used in open fractures with comminuted fractures and bone loss. External fixation, nails, and plates were used in closed fractures. In closed fractures, plates were used in 87.0% (61 out of 70) of operations. Medial plates were placed in only four patients (5.0%) who suffered closed distal femur fractures. Bone grafting was reported in 31.5% (23 out of 73) of patients, all of whom had closed fractures.

Plate length(s), plate working length(s) (i.e., the length of the fracture zone between the most distal screw of proximal fragment and the most proximal screw of the distal fragment), and the length(s) proximal to the fracture were also recorded for closed and open fractures. Closed fractures used plates with a median plate length of 240.6 cm (193.0 cm to 294.6 cm), while the open fracture had a median plate length of 195.0 cm (173.0 cm to 217.0 cm). The median plate working lengths of closed and open fractures were 70.5 cm (40.6 cm to 109.0 cm) and 67.3 cm (55.0 cm to 79.5 cm), respectively. The median proximal length to the fracture was 129 cm (101.0 cm to 165.8 cm) overall, with closed fractures having a longer length compared to open fractures (130 cm vs 99.2 cm, $P = 0.19$, Table 4).

Outcome measures

Clinical signs of infection occurred in 8.0% (6 out of 73) of total cases, and they occurred exclusively in closed fractures. The surgical sites infection were treated by wound care and antibiotics in superficial infection or irrigation and debridment in deep infections. There was no statistical significance ($P = 0.6$) found between infection rate and fracture type. Reoperation occurred in 11 cases (15.0%), nine of which were in closed fractures, and two cases occurred in open fractures ($P = 0.011$, Table 5).

Table 3. Operative Procedure Characteristics

	Type of Fracture			
Factor	**Cohort**	**Close**	**Open**	***P*-value**
N	**73**	**70**	**3**	
Fixation Method				
External	3 (4.0%)	1 (1.0%)	2 (67.0%)	<0.001
Nail	8 (11.0%)	8 (11.0%)	0 (0.0%)	
Plating	62 (85.0%)	61 (87.0%)	1 (33.0%)	
Nail alone				
Nail alone	71 (97.0%)	68 (97.0%)	3 (100.0%)	0.77
Nail + plate	2 (3.0%)	2 (3.0%)	0 (0.0%)	
Medial plate				
No	69 (95.0%)	66 (94.0%)	3 (100.0%)	0.67
Yes	4 (5.0%)	4 (6.0%)	0 (0.0%)	
Bone Grafting				
No	50 (68.5%)	47 (67.1%)	3 (100.0%)	0.54
Yes	23 (31.5%)	23 (32.9%)	0 (0.0%)	
Graft in Primary Surgery				
No	55 (75.3%)	52 (74.3%)	3 (100.0%)	0.57
Yes	18 (24.7%)	18 (25.7%)	0 (0.0%)	
Graft in Secondary Surgeries				
No	68 (93.2%)	65 (92.9%)	3 (100.0%)	0.63
Yes	5 (6.8%)	5 (7.1%)	0 (0.0%)	

Data is presented as number and percentage. Two-sided Chi-square test was used. Significance was set at p-value less than 0.05.

Table 4. Construct Characteristics

	Type of Fracture			
Factor	**Cohort**	**Close**	**Open**	***P*-value**
N	**73**	**70**	**3**	
Plate length	240.0 (193.0, 290.0)	240.6 (193.0, 294.9)	195.0 (173.0, 217.0)	0.26
Plate working length	70.5 (44.6, 108.8)	70.5 (40.6, 109.0)	67.3 (55.0, 79.5)	0.84
Length proximal to the fracture	129.0 (101.0, 165.8)	130.0 (101.0, 170.0)	99.3 (80.5, 118.0)	0.19

Data is presented as median and interquartile range (IQR). Mann-Whitney U test was used. Significance was set at p-value less than 0.05.

Table 5. Outcome Measures

	Type of Fracture			
Factor	**Cohort**	**Close**	**Open**	***P*-value**
N	**73**	**70**	**3**	
Follow Up Time (months), median (IQR)	14.2 (3.0, 17.2)	12.9 (3.0, 15.5)	44.7 (43, 46.5)	
Infection				
No	67 (92.0%)	64 (91.0%)	3 (100.0%)	0.60
Yes	6 (8.0%)	6 (9.0%)	0 (0.0%)	
Reoperation				
No	62 (85.0%)	61 (87.0%)	1 (33.0%)	0.011
Yes	11 (15.0%)	9 (13.0%)	2 (67.0%)	

Data is presented as number and percentage or median and interquartile range (IQR). Mann-Whitney U test was used. Significance was set at p-value less than 0.05.

Independent risk factors for reoperation

When assessing patient risk factors that resulted in reoperation, age at presentation was the only statistically significant patient demographic (OR = 0.96, 95.0% CI: [0.92, 0.99]). All other patient demographics had no statistically significant association with reoperation rate (Table 6). MVA, open fracture, and AO/OTA type C classification were all found to significantly increase the likelihood of reoperation. The use of a bone graft at initial surgery was found to decrease the odds of requiring reoperation (OR = 0.2, 95.0% CI: [0.05, 0.77). All other operation characteristics had no significance on necessity of reoperation. Case example was presented in figures 1 through 3.

DISCUSSION

Careful preoperative planning (e.g., understanding the fracture pattern, assessing bone quality, and selecting implants) can promote favorable operative outcomes, but many risk factors are not in the surgeon's control and can affect surgical outcomes. This study focused on identifying the risk factors associated with healing complications and implant failure in patients that suffered distal femur fractures. The authors found that patient age at presentation, mechanism of injury, type of fracture (including the AO/OTA classification) and bone graft use can all impact the odds of reoperation.

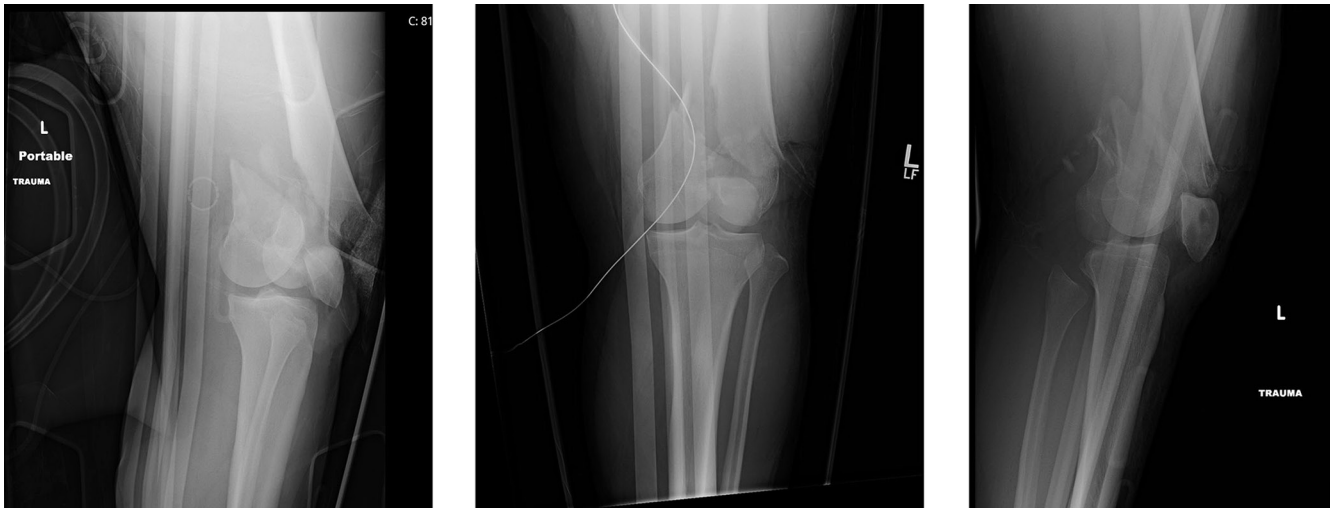

Figure 1. *A 19-year-old male with left distal femur intra-articular fracture (AO/OTA 33-C3) s/p polytrauma due to MVA. Left picture: Lateral view of an open comminuted fracture of the distal femur shaft extending intra-articular and separating both femoral condyles. Middle Picture (AP view) and Right picture (Lateral view): Comminuted, displaced distal femoral meta-diaphyseal fracture and intra-articular extension.*

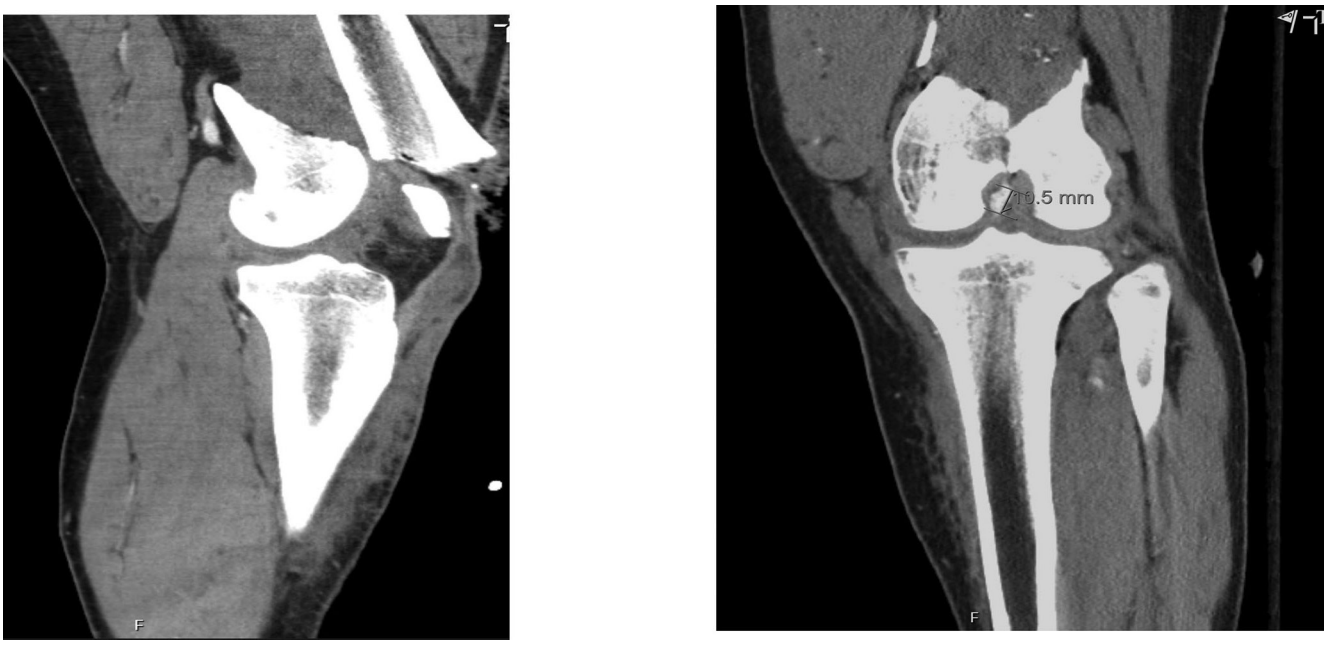

Figure 2. *Preoperative CT imaging. Lateral view (left) and anteroposterior (right): Open comminuted fracture of the distal femoral metaphysis with intra-articular extension into the intercondylar notch.*

Several reports have studied the impact of substance use and comorbidities on fracture healing and infections, but known risk factors pertaining to distal femur fractures are limited. The authors expected to see a positive correlation between current tobacco users and reoperation rates, but the results showed no significance between tobacco-use status and odds of reoperation (Table 6). This directly contrasts previous reports that have shown that smokers have an increased risk and experience more complications due to delayed bone healing.[18,19] This could be due to the low number of smokers (22.0%, 16 out of 73) in this cohort, and the low sample size.

Furthermore, this study found no association between alcohol use and odds of reoperation (Table 6). This finding is in opposition to previous literature statements that alcohol use leads to postoperative complications by impairing callus and new bone formation.[10,20,21] This study also found no statistically significant correlation between drug use and the outcome measures. The effects of drugs on fracture healing are not well clarified. But, in a literature review by Richards et al. [22], investigators found that opioids have a well-documented negative effect on fracture healing in both animal models and retrospective studies. Another study found that patients with ankle fracture who had x-positive urine drug screens were at increased risk of non-union and deep infections.[23]

The effect of certain comorbidities on fracture healing is well-established in the literature. For

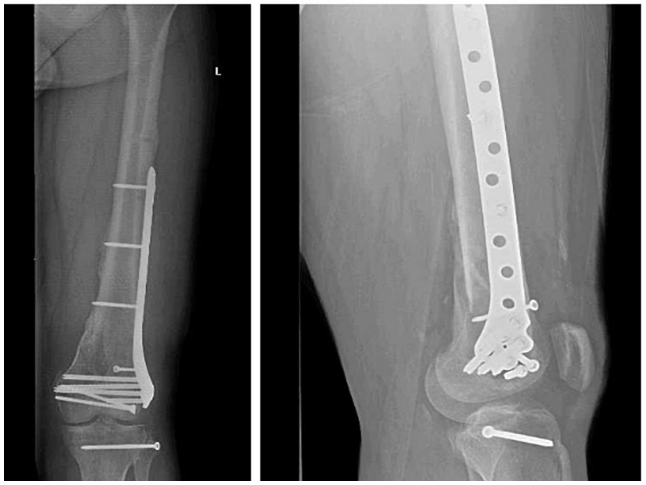

Figure 3. *Anteroposterior (left) and lateral (right) radiographs at 8 months follow-up show hardware in place with acceptable alignment and healed femur fracture with callus formation. Patient was full weight bearing at this point, denies any pain and regained full knee range of motion.*

example, diabetes is recognized to substantially interfere with bone and soft-tissue healing leading to prolonged time to union or non-union complications.[10-12] This is primarily due to the decreased vascularization and altered biochemical properties of the callus formed during healing.[24,25] Osteoporosis is another comorbidity, as it can result in implant anchorage problems due to fragile bone and poor healing capacity of the osteoporotic bone.[25] In this cohort, 60.0% (44 out of 73) of the patients had more than one comorbidity. It is also important to recognize that this cohort was based on this population, which is approximately 80.0% Hispanic or Latino. Per the United States Census Bureau, Hispanics have an 80.0% higher rate of diabetes than non-Hispanic whites.[26] Additionally, this cohort was predominantly female (59.0%) with an average age of 62 years old, both of which are risk factors for osteoporosis.[10,25] In this cohort, presence of one or more comorbidity did not increase the likelihood of reoperation. Low sample size likely accounts for this lack of association.

Fracture type and its relation to the incidence of superficial infection and reoperation was also studied. In closed fractures, a majority of the patients did not incur infections (91.0%) or need reoperations (87.0%). In cases of open fractures, 67.0% of the cases required reoperation. This finding correlates with an epidemiological study that found open fractures were a significant risk factor (OR, 1.66; 95.0% CI, 1.55-1.77) for non-union.[27] This is likely as a result of high-energy trauma sustained during the injury event causing soft tissue injury and damage to bone vascularity.[28] Higher rates of infection and non-union are known complications of open femur shaft fractures especially among the Gustilo-Anderson Type II and III open fractures.[29] This study also found increased odds of

Table 6. *Unadjusted Risk for Reoperation*

Risk factors	Odds ratio	Lower limit	Upper limit	*P*-value
Demographics data				
Age at presentation	0.96	0.92	0.99	0.025
Male versus Female	2.97	0.78	11.24	0.11
Non-smoker versus smokers	0.81	0.12	5.42	0.83
Drug use versus none	0.96	0.91	1.006	0.72
Alcohol use versus none	2.21	0.49	9.93	0.30
Presence of comorbidity versus none	0.51	0.13	2.00	0.33
Injury data				
MVA versus fall injury	4.60	1.14	18.52	0.032
Open versus Close fracture	13.6	1.11	165.2	0.041
AO/OTA classification: C versus A	9.29	1.11	77.66	0.040
Operation characteristics				
Bone graft versus none	0.20	0.05	0.77	0.019
Primary bone graft versus none	0.64	0.12	3.28	0.59
Plate length	0.997	0.986	1.008	0.56
Plate working length	1.003	0.987	1.019	0.73
Length proximal to the fracture	0.982	0.963	1.001	0.06

Univariate logistic regression analysis was applied. Significance was set at p-value less than 0.05.

reoperation with distal femur fractures caused by MVA (Table 6).

Among fixation types, the most common form used was distal femur locking plate fixation (85.0%) followed by intramedullary nails (IMN) (11.0%). The type of plate was chosen based on the operating surgeon's discretion. Closed fractures were primarily managed with plates (87.0%), and open fractures were primarily managed with external fixator devices (67.0%). Recently, there is increasing trend toward using combined impalnts (combined plate and nail) in elderly patients or patients with multiple comorbities to allow early ambulation and weight bearing. Nail/plate combination technique was not used in this study. In the current study, the utility of various fixation methods have been well-described in the literature. Fixed-angle blade plates were traditionally used, as their design creates stable fixation with alignment control in multiple planes, but other reports show that closed intramedullary nails have gained favor as a form of minimally-invasive method.[8,9,30] Pre-contoured distal femur locking plates have become popular in orthoapedics because they offer adequate

compression, and bridge plating allows for adequate callus formation in severe comminution.[8] Increased external fixation rates in these open fracture cases mirror previous literature, as external fixation can be used in severely comminuted open fractures due to the benefit of minimizing further soft tissue damage and acceptable union rates.[8,9] The authors presume plates were predominantly used for multiple reasons, including surgeon preference and prior evidence of augmented fracture reduction and restored stability.[8,9,31]

The majority of patients in the current study were treated with stainless steel distal femur locking plates. Plate material may have impact on fracture healing. Studies have shown a significant difference between plate material and callus formation. Henderson et al. [16] found more callus formation with titanium plates in distal femur fracture at 6 weeks, 12 weeks, and 24 weeks compared with stainless steel plates. Another alternative plate material is the carbon-fiber-reinforced (CFR) polymer implant, which offers less stiffness and improved biomechanics. Despite the theoretical advantage, CFR is associated with a longer time to union and higher displacement rates as compared to traditional titanium plates.[17]

Several factors of this study may lead to a limit of external validity. The cohort included only 73 patients and was not evenly distributed amongst fracture type. Univariate regression analysis was performed, as the small sample size and uneven distribution amongst fracture types limited the authors' ability to perform multivariate analysis. Ideally, there would have been a similar number of open and closed fracture cases. This institution has a large Hispanic population, and the comorbidities of diabetes and osteoporosis may have played a larger role than anticipated. Regarding social behaviors (e.g., tobacco, alcohol, drug use), the authors were not able to specify the quantity used by the patients, as they retrospectively investigated their charts. The authors were also not able to specify the type of drug used. Lastly, the type of fixation used in each case was not equally represented. This may have been due to the surgeon's confidence in a certain technology, but it risks skewing the data. Further research must be conducted in understanding whether gender affects healing time and reoperation rates.

CONCLUSION

Several risk factors may lead to reoperation following operative fixation of the distal femur. This study showed that age of presentation, mechanism of injury, type of fracture, AO/OTA classification, and bone-graft use can all impact the odds of reoperation. While some of these factors cannot be controlled, having a better understanding of the risk factors associated with reoperation of distal femur fractures can lead to better management of these fractures by orthopaedic surgeons.

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