

Research Article

Weight-bearing as tolerated following distal femur fracture surgically treated with Far Cortical Locking screws

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Objectives

To review outcomes of a consecutive, non-selected series of distal femur fractures treated with a dynamic plate construct and allowed unrestricted weight bearing immediately after surgery.

Design

Retrospective consecutive case series.

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b Stephanie's drive to serve vulnerable populations, specifically children, has motivated her to pursue a career in the healthcare industry. Additionally, her clinical and chemical research has allowed her to develop her creative problem solving skills. Stephanie seeks to connect with patients and develop innovative solutions to meet their unique needs.

Stephanie graduated from the University of Notre Dame in 2022. She is in the Harvard Medical School Class of 2026.

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c Ellie Jitto graduated from Oregon State University in 2021 with a B.S. in BioHealth Science. She is currently working as an EMT in Austin, TX with the goal of attending medical school in the near future. She has aspirations of becoming an orthopedic trauma surgeon.

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d M. Mitch Herbert was born and raised in Eugene, Oregon, and graduated from Montana State University in 2018 with a major in cell biology and neuroscience. He was a team captain of the Montana State University football team as a wide receiver. After college graduation, he worked for two years as a medical scribe and research assistant at the Slocum Center for Orthopedics & Sports Medicine in Eugene, Oregon, before starting medical school at the Columbia University Vagelos College of Physicians & Surgeons.

He is currently a 3rd year medical student and aspiring orthopaedic surgeon with a specific interest in sports medicine.

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e Connor Fitzpatrick graduated in December 2022 from Loras College with a Bachelors degree in Psychology.

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f Serving most recently as the Executive Director of the Slocum Research and Education Foundation, Erin has been at the forefront of clinical research in orthopedic joint replacement, trauma, and sports medicine for the last decade. Erin earned a doctorate in Public Health, in the area of health policy, from Oregon State University in 2017 and a MPH in Epidemiology from San Diego State University in 2004. She has previously held academic appointments at University of Oregon and Oregon State University, as well as a Visiting Scientist position at Oregon Health & Science University.

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Setting

Level 2 trauma center

Patients/Participants

Thirty-one consecutive distal femur fractures in 29 patients with 33A and 33C fractures stabilized with a distal femur locking plate and Far Cortical Locking diaphyseal screws.

Intervention

All patients were allowed immediate unrestricted weight bearing with assistive devices post-surgery.

Main Outcome Measure

Loss of reduction from immediate post-operative alignment, implant failure, nonunion, and medical complications.

Results

No loss of alignment greater than three degrees in the lateral distal femoral angle was noted at healing. Two implant failures occurred, one in the first five weeks and another in an established nonunion. Mortality at one year was 6.5%. Readmission for medical complications was noted in 6.5% of patients.

Conclusions

Immediate, unrestricted weight bearing after fixation of 33A and 33C distal femur fractures with a dynamic plate construct may be safe, with a low risk of implant failure or loss of coronal plane alignment. Relative to historical reports, morbidity and mortality in our cohort were improved with early weight-bearing.

Level of Evidence

Therapeutic Level IV, case series

INTRODUCTION

Elderly distal femur and hip fracture patients are similar—both have poor bone quality, multiple underlying comorbidities, and high rates of postoperative morbidity and mortality (Myers et al. 2018; Konda et al. 2015; Pean et al. 2015; Moloney et al. 2016; J. R. A. Smith et al. 2015). Hip fracture patients, however, are allowed unrestricted post-operative weight-bearing, while the combination of poor bone quality and concerns surrounding the strength of fixation leads most surgeons to restrict weight-bearing for 6-8 weeks following distal femur fracture fixation (Campana et al. 2020; Beltran, Gary, and Collinge 2015; W. R. Smith et al. 2016). Improved outcomes following unrestricted weight-bearing after hip fracture surgery has generated an interest in allowing distal femur fracture patients to weight-bear as tolerated postoperatively (W. R. Smith et al. 2016; Hussain, Dailey, and Avilucea 2018; Lieder et al. 2021; Poole et al. 2017; Bruggers, Jeray, Tanner, et al. 2020).

In addition to fixation failure after surgery, recent studies have confirmed a 14-22% rate of delayed healing associated with plate fixation of distal femur fractures (Henderson, Bottlang, Marsh, et al. 2008; Lujan et al. 2010). Extremely stiff plate constructs limit fracture site motion and inhibit healing (Bottlang et al. 2015, 2010; Ricci and Borrelli 2007). Strategies to decrease construct stiffness while maintaining construct strength have resulted in improved healing rates (Linn et al. 2015; Richter et al. 2015; Henschel et al. 2017). One specific method that has shown

improved rates of healing in the distal femur is the use of Far Cortical Locking (FCL) screws in the diaphysis (Bottlang, Doornink, Fitzpatrick, et al. 2009). This flexible construct allows fracture site motion to promote early callus while distributing the load over the entire implant to avoid stress risers that might lead to implant failure (Bottlang and Feist 2011).

Using a strong but flexible implant may decrease the risk of construct failure during loading and allow safe early weight-bearing following plate fixation of distal femur fractures. This study aims to determine the outcomes in a consecutive series of patients allowed immediate unrestricted weight-bearing following distal femur fracture fixation with dynamic plate constructs. We hypothesized that unrestricted weight bearing following locked plate fixation of distal femur fractures with a flexible plating system would result in no loss of alignment or implant failure.

MATERIALS AND METHODS

We retrospectively reviewed a consecutive, nonselected series of distal femur fractures (OTA type 33a and 33c) treated by a single surgeon using lateral distal femur locking plates with FCL screws in the femoral diaphysis (MotionLoc, ZimmerBiomet, Warsaw, IN) and one of 3 plates (titanium Non-Contact Bridging, (NCB), distal femur; titanium NCB periprosthetic distal femur; or stainless steel Zimmer Periarthicular Locking Plate, (ZPLP), distal femur; ZimmerBiomet, Warsaw, IN). All three plating systems are designed



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to allow the same dynamic mechanical environment at the fracture site, with a biphasic stiffness curve allowing controlled axial motion. Inclusion criteria were any distal femur fracture, including periprosthetic fractures, in patients greater than 18 years old treated between 2011 and 2018. Exclusion criteria included pathologic fractures, patients treated with intramedullary nails, patients who were non-ambulatory pre-injury, patients who were not allowed to weight-bear as tolerated secondary to associated injuries, patients who followed up in other states and patients with preexisting nonunions. No patients were excluded based on fracture comminution or bone loss.

A standard surgical technique was used in all patients (Fitzpatrick et al. 2013). A lateral incision was made over the distal femur and extended past the knee joint if an intraarticular fracture was noted. All articular fractures were anatomically reduced and either fixed with independent lag screws or held in place with reduction clamps while screws were placed through the plate. This formed a reduced 'articular block' into which distal fixation was placed. Fixation in the articular block was accomplished using standard polyaxial titanium screws (NCB plates) or standard fixed angle stainless-steel screws (ZPLP plates). The comminuted metaphyseal segment was bridged with no attempts at fixation. Diaphyseal fixation was performed percutaneously. To preserve the dynamic construct, only FCL screws were placed in the diaphysis (no lag screws, no standard locking screws). NCB periprosthetic plates were preferred to allow more points of fixation in the distal fragment. Locking caps were placed on all screws when the NCB system was used. When stainless steel plates were selected, the screws were threaded into the plate. The mechanical axis was measured intraoperatively using the electrocautery cord from the center of the hip to the center of the ankle. The mechanical axis was required to be anatomic, as defined by the cord passing in the central 2 cm of the knee, or fixation was revised (Figure). All patients were placed in a hinged knee brace and allowed full range of motion immediately after surgery. Unrestricted weight bearing with the use of walking aids (crutches or a walker) encouraged after surgery in all patients.

After approval from the Institutional Review Board (PeaceHealth System IRB, Eugene, OR), patient charts and radiographs were reviewed. Demographic information, including pre-injury medical comorbidities, were collected. The injury mechanism was categorized into high energy (motor vehicle crash) versus low energy (ground level fall). Injury radiographs and, when available, computerized tomography (CT) scans were evaluated to classify the fracture pattern using the AO/OTA fracture classification. The coro-

nal alignment on the immediate postoperative radiograph was measured and compared to the alignment on the final healed radiograph. Fractures were judged to be healed by the treating surgeon (D.C.F.) when there was bridging callus on three of four visible cortices (Strotman et al. 2017; Lack et al. 2014). Presence or absence of rotational deformity was not documented in retrospective exam findings. Complications were recorded, including those related to fixation, medical complications, readmissions, and revision surgeries through one-year post-operatively.

The primary outcome variables were failure of fixation and nonunion. Fixation failure was defined as either implant failure (breakage or loss of fixation) or change in coronal alignment of greater than 5 degrees relative to the immediate postoperative radiographs. Nonunion was defined as lack of bridging callus on three of four visible cortices at 6 months post-surgery. Secondary outcome variables included postoperative medical complications not related to fixation: readmission, infection, and mortality.

RESULTS

Chart review of our electronic billing database identified 37 patients treated with flexible plate constructs for distal femur fractures over the 8-year study period. After applying exclusion criteria, 31 patients were included. Six patients were excluded because they were non-weight bearing preinjury (n=3) or were not allowed to weight bear because of other associated injuries (n=3). Characteristics of the case series are shown in Table 1. The average age of the study population was 74 ± 12 years and 29 of the 31 (94%) were female. Eleven (29%) of the patients were diabetic and 14 (39%) were current or former smokers. The mean BMI was 31 ± 8 kg/m², with 16 (51.6%) of the patients in the case series defined as obese (BMI of greater than 30) and seven classified as morbidly obese (BMI greater than 40). There were 23 OTA 33A extra-articular fractures and eight OTA 33C intraarticular fractures. Nine fractures were considered high energy while 22 resulted from low energy ground level falls. There were three open fractures and 13 periprosthetic fractures; 11 above a total knee arthroplasty and two below a hip implant that affected fixation of the proximal portion of the plate.

NCB periprosthetic distal femur plates were used in 23 patients, NCB distal femur plates in five patients and ZPLP stainless steel plates were used in three patients. The average number of screws in the articular segment was 6 ± 0.8 . The number of FCL screws used in the diaphysis ranged from 4-5 with an average of 4.1 ± 0.4 . The average screw fixation span (distance from the most distal to most proximal



Figure. Surgical repair of distal femur fracture using Far Cortical Locking screws. The weight bearing axis was checked to assure a line from the center of the hip to the center of the ankle passed through the central 2 cm of the knee.

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screw) in the diaphysis was 151 ± 39 mm and the average working length was 123 ± 47 mm.

The average time from admission to surgery was 1.5 ± 1.2 days. Length of stay was 6.5 ± 4.4 days. Most patients ($n=27$) were discharged to a skilled rehabilitation center, while a small group were discharged to home ($n=4$). There were two readmissions (6%) in the first three months after surgery for medical complications.

[Table 2](#) reports surgical outcomes and complications. Patients were followed until the fracture was healed or revision was required for implant failure or nonunion. Three patients did not return for follow-up. Two patients died before follow-up was complete (6.5%). Average follow up time for the remaining patients was 18.4 ± 10.5 weeks. There was one early plate fracture that required revision to an intramedullary nail at 5 weeks and one nonunion with plate breakage that required revision to an intramedullary nail at 14 months. Ten of the fractures were healed by 3 months (42%), 18 (75%) were healed by 6 months and 23 (96%) were healed by 9 months. The remaining fracture healed at one year after surgery without an intervention. There were two infections (6%); one superficial infection that resolved with oral antibiotics and one deep infection following an open fracture that required multiple debridements.

For the 24 patients without reoperation for non-union and/or implant failure who completed radiographic follow up, average lateral distal femoral angle fracture alignment post operatively was 96.7 degrees. Average alignment after

healing was 95.7 degrees. No fracture experienced an alignment change of greater than 3 degrees of varus or valgus over the course of healing. Of the 8 intraarticular fractures followed to healing, there was no loss of reduction of the articular fracture fragments. For a complete description of this nonselected consecutive series of patients, it is important to report the outcomes of the patients who were excluded from the study population because of pre- or post-operative non weight bearing status. Of the 6 patients excluded, 4 (67%) resulted in a nonunion.

DISCUSSION

Most authors recommend limited weight bearing or non-weight bearing ambulation after plate fixation of distal femur fractures (Campana et al. 2020; Beltran, Gary, and Collinge 2015; W. R. Smith et al. 2016). These recommendations are largely predicated on concern for fixation failure in the weak metaphyseal bone of the distal femur. We hypothesized that unrestricted weight bearing following locked plate fixation of distal femur fractures with a flexible plating system would result in no loss of alignment or implant failure. Our results from this non-selected, consecutive series of distal femur fractures partially confirmed the hypothesis. No patient experienced a loss of alignment greater than 5 degrees, including a small number of patients with intraarticular fractures. There was a single early

Table 1. Patient characteristics,* consecutive distal femur fractures treated with far cortical locking screws, 2011-2018.

	n = 31	%
Age (mean, range)	73.8 (41-99)	
Gender		
Female	29	93.5
Male	2	6.5
BMI (mean, range)	31.7 (17-49)	
Normal (< 25.0)	6	19.3
Overweight (25.0-29.9)	9	29.0
Obese	16	51.6
Class 1 obesity (30.0-34.9)	7	19.3
Class 2 obesity (35.0-39.9)	3	9.7
Class 3 obesity (≥ 40)	6	22.6
Tobacco Use		
Current	9	29.0
Former	5	16.1
Mechanism of injury		
Fall from standing height	22	71.0
High energy	9	29.0
Diabetes	11	35.5
Periprosthetic		
Knee	11	35.5
Hip	2	6.5
Open fractures	3	9.7
OTA Fracture Classification		
33A1	1	3.2
33A2	11	35.5
33A3	11	35.5
33C1	0	0.0
33C2	6	22.6
33C3	2	6.5

*29 patients, 31 distal femur fractures.

plate failure and one case of a late plate failure in a patient with an established nonunion.

Based on improved clinical outcomes and relatively low failure rates when allowing unrestricted weight bearing after proximal femur and femoral shaft fractures, the concept of unrestricted weight bearing after distal femur fracture fixation with a single lateral plate is becoming more popular. Several authors have reported good results allowing selected patients unrestricted weight bearing after plate fixation of distal femur fractures. Smith et al. evaluated 54 consecutive distal femur fractures above total knee prostheses treated with a standard protocol that included unrestricted weight bearing immediately after surgery (J. R. A. Smith et al. 2015). They noted three implant failures and recommended all periprosthetic distal femurs fixed with locking plates be allowed unrestricted weight bearing after surgery. Lieder et al. retrospectively reviewed 135 patients

with extra-articular distal femur fractures treated with a lateral plate or retrograde intramedullary nail (Lieder et al. 2021). Weight bearing after surgery was allowed in 56 patients, there was no difference in implant failure or loss of reduction between the groups. Bruggers et al. performed a prospective study allowing early weight bearing in 11 of 46 distal femur fractures treated with lateral plate fixation (Bruggers, Jeray, Tanner, et al. 2020). They noted two implant failures in the non-weight bearing group, none in the early weight bearing group. Poole et al. retrospectively evaluated 127 distal femur fractures, of which 107 were allowed immediate unrestricted weight bearing (Poole et al. 2017). Four patients (3%) required reoperation for loss of fixation. To our knowledge this is the first case series of single implant fixation that allowed unrestricted weight-bearing in all patients, regardless of fracture pattern.

Table 2. Surgical outcomes of patients* with distal femur fracture treated with far cortical locking screw and allowed to weight-bear as tolerated post-operatively (n=31).

	n = 31	%
Weeks to fracture healing (mean, standard deviation)	19.8 (9.9)	
Infection		
Superficial	1	3.2
Deep	1	3.2
Implant loosening	0	0.0
Implant failure	2	6.5
Painful hardware	3	9.7
Delayed union (> 6 months healing)	5	16.1
Nonunion	1	3.2
Reoperation	3	9.7
Medical complications	2	6.5
Lateral Distal Femoral Angle		
Postoperative	96.7° (4.7°)	
Healing	95.7° (4.8°)	
Mean change	1.5° (0.9°)	
Alignment range	2.4° varus - 3.1° valgus	

*29 patients, 31 distal femur fractures.

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In the current study, all patients used walking aids to avoid stumbles that might cause excessive loads on the fixation construct. Limited weight bearing requires a four-fold increase in the energy required for ambulation (Ricci and Borrelli 2007) and causes altered gait mechanics (Linn et al. 2015) both of which increase the difficulty of mobilization for elderly patients. There is evidence that elderly fracture patients who are allowed to ambulate immediately after surgery suffer lower rates of morbidity and mortality. The mortality rate following distal femur fracture fixation is high, ranging from 13-25% at one year (Myers et al. 2018; Moloney et al. 2016; Kammerlander et al. 2012; Streubel et al. 2010). Compared to existing literature, our case series had a much lower one-year mortality of 6.5%. The post-operative morbidity following distal femur fixation is also high, with 37% experiencing one medical complication and 11% suffering from at least two complications during the hospital stay (Moloney et al. 2016; Kammerlander et al.

2012). Our patients had a lower morbidity with only 9.6% having documented post-operative medical complications.

Limitations of this study include small case series sample size, mix of both periprosthetic and native knee fractures, and lack of non-weight bearing comparison group. Although the inclusion criteria included patients over 18, the youngest patient in this series was 41 and the average age was 73, meaning the results may not be valid for the young patients with distal femur fractures. Of note, the small number of intraarticular fractures in this group were allowed unrestricted weight bearing with no adverse effects. Patients were placed in a brace for six weeks after surgery, the compliance and true duration of bracing was not recorded. Previous studies (Poole et al. 2017; Bruggers, Jeray, Tanner, et al. 2020) also included small numbers of intra-articular fractures in the early weight-bearing and noted no adverse effects. These results are encouraging, but the number of intraarticular fractures in all three studies is too small to draw meaningful conclusions.

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Many of the failures in previous studies included screw loosening and plate failure. Biomechanical studies show both locking and standard compression plating techniques result in stress risers which may lead to construct failure during weight-bearing (Chen et al. 2002; Beaupré et al. 1992; Sommer et al. 2003; Bottlang, Doornink, Byrd, et al. 2009). The use of a dynamic FCL fixation construct allows forces to be evenly distributed over the entire segment of diaphyseal fixation, limiting excessive loads at a single screw which might lead to failure. This may limit the applicability of these results to fractures fixed with standard locking constructs. Future research should include larger numbers of non-selected patients with standard locking plates to better understand the transferability of these results.

CONCLUSION

In a consecutive case series, unrestricted weight bearing after distal femur fixation with dynamic locking plate constructs did not lead to loss of alignment or implant failure. Patients experienced lower rates of nonunion, morbidity, and mortality relative to previously published studies.

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