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Working length and proximal screw constructs in plate osteosynthesis of distal femur fractures

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ABSTRACT

Background: The study purpose is to evaluate the working length, proximal screw density, and diaphyseal fixation mode and the correlation to fracture union after locking plate osteosynthesis of distal femoral fractures using bridge-plating technique.
Methods: A four-year retrospective review was performed to identify patients undergoing operative fixation of distal femur fractures with a distal femoral locking plate using bridge-plating technique for the metadiaphyseal region. Primary variables included fracture union, secondary surgery for union, plate working length, and diaphyseal screw technique and configuration. Multiple secondary variables including plate metallurgy and coronal plane fracture alignment were also collected.
Results: Ninety-six patients with distal femur fractures with a mean age 60 years met inclusion criteria. None of the clinical parameters were statistically significant indicators of union. Likewise, none of the following surgical technique parameters were associated with fracture union: plate metallurgy, the mean working length, screw density and number of proximal screws and screw cortices. However, diaphyseal screw technique did show statistical significance. Hybrid technique had a statistically significant higher chance of union when compared to locking ($p = 0.02$). All proximal locking screw constructs were 2.9 times more likely to lead to nonunion.
Conclusions: Plating constructs with all locking screws used in the diaphysis when bridge-plating distal femur locking plates were 2.9 times more likely to incur a nonunion. However, other factors associated with more flexible fixation constructs such as increased working length, decreased proximal screw number, and decreased proximal screw density were not significantly associated with union in this study.

Introduction

Distal femur fractures account for less than 1% of all fractures and 3%–6% of all femur fractures. Epidemiological studies indicate 2 primary distributions of patients: elderly individuals with low-energy mechanisms such as a fall from standing, and younger patients with high-energy mechanisms such as motor vehicle accidents [1–3]. When compared to non-operative management, studies indicate that patients treated with surgery have better outcomes related to alignment, union and function [2]. Simple metaphyseal fractures that are amenable to direct reduction with absolute stability do sometimes occur; however, due to the increasing number of elderly patients with osteoporosis and the higher energy injuries that younger patients are now surviving, distal femur fractures are often associated with highly comminuted metaphyseal segments that are more amendable to indirect reduction techniques and relative stability. Surgical treatment options include plate or intramedullary nail fixation. Non-locking plates have fallen out of favor due to the increased incidence of late varus displacement [4]. Fixed-angle plates have proven to be more effective in resisting the high forces in multiple planes about the distal femur [5]. Anatomically pre-contoured locking plates are popular due to improved fixation in osteoporotic bone and highly complex articular fractures compared to blade or dynamic condylar plates [6,7]. However, locking plates still fail either with proximal or distal screw, or plate breakage. These failures occur in fractures with extensive metaphyseal comminution and in instances of early weight bearing [8,9].

Fixation of distal femur fractures using bridge plating techniques with anatomically pre-contoured locking plates uses

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relative stability principles with the intent of secondary bone healing. Rigid fixation in the setting of a fixed fracture gap results in high strain and is less likely to induce fracture callus or secondary bone healing. However, flexible fixation allows for decreased gap and strain leading to callus formation [10]. Controversy exists as to how to relate this ideal environment to current plating techniques, and numerous biomechanical studies have explored how plate design, plate length, screw length and screw configuration can alter the overall construct stability [11–15].

Working length of a plate construct is defined as the distance between the first screws on either side of the fracture [16]. Some biomechanical studies indicate that increasing the working length of a relative stability fracture construct results in increased flexibility, less strain, and an in theory, improves fracture healing [17,18]. However, very few clinical studies have tried to relate working length to fracture union for distal femur fractures [19,20]. The primary purpose of this study is to evaluate if the working length of lateral anatomically pre-contoured locking plates in distal femur fracture fixation using relative stability techniques affects union rate. We hypothesize that longer working lengths will be associated with higher fracture union rates.

Materials & methodology

Following Institutional Review Board approval, we identified all patients from January 2007 to December 2011 who presented with an acute distal femur fracture (AO/OTA 33) [21,22] to our American College of Surgeons (ACS) Level I academic trauma center. In total, 180 patients were identified. Patients at least 18 years old who underwent open reduction and internal fixation (ORIF) of acute distal femur fractures (open and closed) with a laterally-based locking plate using bridge plate technique were included. Patients were excluded if: they were less than 18 years old, their injury could be treated non-operatively, there was inadequate clinical follow-up, and if operative fixation did not include a lateral-based distal femur locking plate. Plates that were used include the Polyax (DePuy Orthopaedic Inc, Warsaw, IN); Synthes (West Chester, PA): Less Invasive Stabilization System (LISS DF), Locking Condylar Plate, Variable Angle Locking Condylar Plate-first generation, Variable Angle Locking Condylar Plate-second generation; and Non-Contact Bridging Plate (Zimmer, Warsaw, IN). All surgeries were performed by 1 of 5 fellowship-trained traumatologists.

All patient radiographs were reviewed using Centricity Enterprise Web PACS (General Electric Healthcare, Milwaukee, WI). "Working length" of the plate construct was defined as the length from the most distal screw proximal to the fracture to the most proximal screw distal to the fracture measured in millimeters (mm). Plate manufacturers publish the plate length in millimeters and these lengths were used as radiographic markers to template actual working lengths to account for radiographic magnification differences. "Screw density" was defined as the length of the plate proximal to the fracture divided by the number of screws proximal to the fracture. Proximal screw mode refers to the type of screws used in the proximal segment (non-locking, locking, or hybrid). Hybrid mode refers to a proximal screw construct with a combination of locking and non-locking screws.

There were 2 primary endpoints: union without unplanned surgery and all eventual unions including those with unplanned surgeries. Fracture healing status was determined after a review of the attending physician's clinical documentation and radiographic imaging. If there was a discrepancy, then one of the authors reviewed the final radiographs. Radiographic union was defined as at least 3 of 4 cortices with bridging callus on orthogonal plain radiographs. If there was any question of union, the radiographs were reviewed with one of the fellowship-trained orthopaedic surgeons. If union was inconclusive, it was considered to be a nonunion. Unplanned surgeries were classified as all fracture healing surgeries that were not planned at the time of initial fracture management. Fractures with antibiotic spacers and secondary bone grafting procedures were considered planned surgeries.

These endpoints were correlated to patient age, sex, mechanism of injury, history of diabetes, history of nicotine use, open fracture type, the AO/Orthopaedic Trauma OTA Classification (33 A, B, C) [21,22], presence of a prosthesis, and metal alloy type. The primary endpoints were also correlated to working length, proximal screw density, proximal screw mode, and coronal plane alignment after fixation relative to 95°.

Statistical analysis included the Fisher exact text for comparative data and an odds ratio for significant differences. A p-value of <0.05 was considered statistically significant.

Results

Out of 180 patients identified, 96 patients met inclusion criteria and were evaluated. Patients were excluded for the following reasons: 22 fractures with absolute stability constructs with lag screw fixation, 21 patients died prior to union, 12 fractures treated with alternative fixation constructs (intramedullary nailing, medial and lateral plating), 4 partial articular fractures, 4 pathological fractures, 3 patients treated by surgeons who were not fellowship trained trauma surgeons, and 2 patients with simultaneous revision arthroplasty procedures. Another 16 patients were excluded due to a lack of clinical follow-up. The mean follow-up for patients was 584 days (range, 85–2119 days) and 88.5% (85) of patients either had a minimum one-year follow-up or were followed until fracture union.

During the follow-up period, 62 fractures (64.6%) healed without unplanned surgeries while 34 fractures (35.4%) were classified as nonunions. Twelve of thirty-four (35.3%) of the nonunions went on to heal after an additional unplanned fracture surgery. Twenty-two patients (22.9%) were classified as having recalcitrant nonunions. There were 24 males and 38 females with an average age of 60 who healed without additional intervention. Those patients with nonunions averaged 62 years of age and included 11 males and 23 females. Patients with a nonunion were more likely to be smokers (35.3% vs. 25.8%; p = 0.36) and have an open fracture (35.3% vs. 27.4%; p = 0.49). Nonunion patients were less likely to present with a periprosthetic fracture (20.6% vs. 35.5%; p = 0.17) and more likely to present with an intra-articular distal femur fracture (33-C) (61.8% vs. 51.6%; p = 0.39). There were no statistically significant differences in rate of fracture union between the cohorts when considering demographic and fracture characteristics (Table 1). Fall was the most common mechanism of injury (51.0%) followed by motor vehicle accident (35.4%) (Table 2).

Of the 96 fractures, 50 stainless steel plates (52.1%) and 46 titanium (47.9%) were used. There were 12 (12.5%) Polyax plates

Table 1
Demographic and fracture characteristics.

Parameter	Healed (N = 65)	Non-union (N = 34)	*P*
Age (range)	60 (16–96)	62 (29–97)	0.64
>65 years (%)	24 (38.7)	12 (35.3)	0.83
Sex	24M; 38F	11M; 23F	0.66
ASA (range)	3 (2–4)	3 (2–4)	0.42
DM (%)	18 (29.0)	9 (26.5)	1.00
Tobacco (%)	16 (25.8)	12 (35.3)	0.36
Open Fractures (%)	17 (27.4)	12 (35.3)	0.49
AO Classification			
A (%)	8 (12.9)	6 (17.6)	0.56
C (%)	32 (51.6)	21 (61.8)	0.39
Periprosthetic Fracture (%)	22 (35.5)	7 (20.6)	0.17

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