Nonunion and secondary reduction loss complicate open distal femur fractures with bone loss. The authors hypothesized that locking plates decrease subsequent bone grafting yet maintain alignment and immediate post-fixation radiographic features predict primary union. A retrospective chart/radiographic review was performed at a Level 1 university trauma center. Thirty-four adults with 36 open AO/Orthopaedic Trauma Association (AO/OTA) C-type distal femur fractures were studied. All fractures were treated with open reduction, internal fixation with a lateral locked implant with or without antibiotic beads, and subsequent bone grafting. Union required radiographic bridging callus on at least 2 of 4 cortices. Alignment was assessed on initial and united radiographs. Antibiotic beads within a metaphyseal defect defined clinically important bone loss. Eleven (55%) of 20 fractures with bone loss underwent staged bone grafting to achieve union vs 2 (13%) of 16 fractures without bone loss. Antibiotic bead presence was associated with staged bone grafting ($P<.01$). Of those with bone loss and grafting, 3 had posterior cortical bone loss only, 3 had medial and posterior cortical bone loss, and 5 had segmental defects. Of 9 fractures with bone loss not requiring grafting, all had radiographic posterior cortical contact and 7 had radiographic medial cortical contact. Posterior cortical continuity was associated with injuries not requiring bone graft ($P<.001$). Thirty-four had accurate frontal plane reductions and 35 had accurate sagittal plane reductions. Despite metaphyseal bone loss, locking plates obviate the need for routine bone grafting of some open distal femur fractures. Those with radiographic posterior cortical contact are strongly correlated with primary union.
Treatment complications of supracondylar–intercondylar distal femur fractures include nonunion, secondary loss of reduction, and the need for subsequent procedures. However, preservation of osseous viability using indirect reduction methods has led to an increase in fracture union rates without the need for supplemental bone grafting procedures. Similarly, advances in distal fragment fixation appear to have decreased secondary reduction loss.

Open distal femur fractures represent a unique subgroup of injuries that present additional challenges. Specifically, the magnitude of associated soft tissue injury and traumatic bone loss may create an exceptionally unfavorable environment for bone healing, particularly in the supracondylar region. These factors are often worsened due to the necessary surgical debridement to assure removal of foreign and devitalized material from the traumatized area. Because of the typically longer duration required for osseous union, secondary loss of reduction is often an anticipated event, necessitating surgical intervention to expedite or assure union. Given the large spectrum of injury incurred by the soft tissue envelope and the variation in the magnitude of bone loss, parameters to identify clinically relevant bone loss and guide surgical decision making regarding the need for bone grafting is lacking. The ability of fixed-angle screw/plate implants to avoid secondary loss of reduction until catastrophic failure occurs further confounds the indications for bone grafting in these challenging injuries.

The authors hypothesized that indirect reduction and stabilization of open supracondylar femur fractures using fixed-angle screw/plate implants decrease the need for subsequent bone grafting while avoiding secondary loss of reduction. They further hypothesized that the radiographic features at the time of definitive fixation may predict union despite apparent bone loss.

**Materials and Methods**

This retrospective study was performed with the approval of the authors’ institution’s Human Subjects Review Board. Between January 2001 and December 2004 (48 months), all patients sustaining a supracondylar–intercondylar fracture of the distal femur were identified from the institution’s computerized orthopedic trauma database. This database records all operatively managed fractures at the institution since 1989. Fractures are entered and coded according to the AO/Orthopaedic Trauma Association (AO/OTA) fracture classification system by orthopedic trauma fellows trained in this system. Data are stored and manipulated using a commercially available software program (Microsoft Access 2003, Redmond, Washington).

The search identified 51 skeletally mature patients with 54 open supracondylar–intercondylar distal femur fractures, classified as OTA 33 C-type injuries, eligible for review. One patient died prior to definitive fixation and was excluded from further review. Fractures treated with standard nonlocking screw/plate implants (n=12) and patients without a minimum 3-month follow-up (n=4) were also excluded from further evaluation. The remaining 34 adults with 36 open AO/OTA C-type distal femur fractures were considered the study group and were retrospectively reviewed.

Twenty-three men and 11 women had an average age of 45 years (range, 17-82 years). Two patients had bilateral injuries. Twenty-five injuries were caused by motor vehicle or motorcycle collisions. Six patients were injured after a fall from a height, and 3 patients were injured by other mechanisms. According to Gustilo and Anderson and Gustilo et al., fractures were classified as type IIIA, 1 as type IIIB, and 1 as type IIC. Seventeen fractures were further classified as AO/OTA type C2 and 19 as type C3.

**Surgical Technique**

All patients were initially assessed according to Advanced Trauma Life Support guidelines. The open wounds were managed with sterile saline irrigation in the emergency department, followed by application of a sterile bandage, splint, intravenous antibiotics, and tetanus prophylaxis. Formal operative debridement was performed as soon as the patient’s general condition permitted. The goals of surgical debridement included excision of all clinically nonviable skin, subcutaneous tissue, muscle, fascia, and nonarticular bone fragments followed by low-pressure irrigation with 3 to 6 L of sterile saline solution. Thirty-three (92%) fractures underwent operative debridement within 24 hours of admission. Three patients were delayed 2, 4, and 17 days, respectively, secondary to associated life-threatening conditions.

The decision to use temporary skeletal stabilization rather than immediate definitive fixation was at the discretion of the attending surgeon. Factors considered in this decision included the general condition of the patient, the presence of associated injuries, the anticipated complexity of the articular and supracondylar reconstruction, and the local soft tissue condition. In patients treated with temporary skeletal stabilization (spanning external fixation/proximal tibial skeletal traction), the time delay to definitive fixation was based on the patient’s medical stability and the management of other life- or limb-threatening injuries. The average interval from injury to definitive surgical treatment for the entire group was 4 days (range, 0-17 days).

Definitive surgical stabilization was performed in a uniform manner. A lateral-based exposure was performed to provide direct visualization of the articular injury. The lateral exposure and traumatic wounds were incorporated in 24 patients with lateral or anterolateral traumatic wounds. Closed anterior- or medial-based traumatic wounds were not reopened (n=12). Articular fragment reduction and stabilization were typically performed initially and by direct visualization, followed
by indirect reduction of the supracondylar area using a variety of techniques alone or in combination, and assessed radiographically. These techniques included strategically placed sterile bumps, external fixation, Steinmann pins, and reduction clues from the laterally applied fixed-angle screw/plate implant. Care was taken to avoid direct manipulation and reduction of comminuted, but viable, supracondylar bone fragments. Definitive stabilization was achieved with a laterally applied submuscular fixed angle screw/plate implant inserted using a retrograde insertion. Specifically, 33 fractures were stabilized with the distal femoral Less Invasive Stabilization System (Synthes, Paoli, Pennsylvania), and 3 fractures were stabilized with Locking Condylar Plates (Synthes).

Twenty-five fractures were treated acutely with manipulative reduction and application of knee-spanning temporary external fixation. Eight fractures were managed with acute open reduction and internal fixation, and 3 fractures were temporized with proximal tibial skeletal traction. Thirty-three patients underwent operative fracture debridement within 24 hours of presentation. In patients treated with temporary external fixation or skeletal traction, the average time to definitive fixation was 3.4 days. Definitive bone stabilization was performed through a lateral-based incision using a minimally invasive technique.

Fracture union was defined as bridging callus on 2 of 4 cortices on biplanar radiographs combined with a reduction of patient symptoms. Radiographic data were available using the picture archiving and communication system and were reviewed by 2 trauma fellowship–trained orthopedic attending surgeons. Agreement was obtained by consensus. Initial and united anatomic lateral distal femoral angles (81°±5°) were evaluated on anteroposterior views. Sagittal plane reductions were evaluated on lateral views. Clinically significant bone loss was defined as the radiographic presence of antibiotic beads within a cavity metaphyseal defect. All patients had a minimum 3-month follow-up.

**RESULTS**

Average follow-up was 13 months. Twenty fractures had polymethylmethacrylate (PMMA) antibiotic beads placed within a metaphyseal defect, whereas 16 fractures did not receive beads. Of those fractures treated initially with PMMA beads, 11 (55%) underwent staged bone grafting at an average of 70 days (range, 47-136 days) after definitive fixation to achieve union. Conversely, of the 16 fractures not treated with PMMA beads, 2 (13%) were bone grafted at 90 and 166 days, respectively, to achieve union. The presence of PMMA beads was significantly associated with subsequent staged bone grafting to obtain union (P<.01).

Of those with PMMA beads and staged bone grafting, 3 had posterior cortical bone loss, 3 had medial and posterior cortical bone loss, and 5 had segmental defects. Of the 9 fractures with beads not requiring bone graft, all had a radiographic appearance of posterior cortical contact; 7 had a radiographic appearance of medial cortical contact. Using Fisher’s exact test, the radiographic appearance of posterior cortical continuity was strongly associated with injuries not requiring bone graft (P<.001), despite the presence of PMMA beads. The presence of medial cortical contact was associated with injuries not requiring bone grafting, but the result was not statistically significant (P=.07).

Two nonunions occurred. One occurred in a patient with segmental bone loss treated with staged bone grafting. Despite this, the fracture required revision plating and additional bone grafting to ultimately obtain union. The second nonunion occurred in a patient treated without PMMA beads or staged bone grafting. This patient ultimately developed an oligotrophic nonunion successfully treated with revision plating and supplemental bone grafting. Thirty-four of 36 fractures had accurate frontal plane reductions, and 35 of 36 had adequate sagittal plane reductions. Reduction loss (5° varus) occurred in 1 patient.

**DISCUSSION**

Fixed-angle screw/plate implants with indirect reduction techniques have been demonstrated to be successful in the treatment of supracondylar distal femur fractures without requiring supplemental bone graft to achieve union. However, the limits of obtaining fracture union and maintaining fracture stability with fixed-angle screw/plate devices may be taxed in situations of overt bone loss and worsening soft tissue injury, as encountered in the open supracondylar distal femur fracture. However; identification of parameters that may aid in determining fracture patterns that may or may not heal, particularly in the face of bone loss, is lacking. Accordingly, the current study demonstrated that fixed-angle screw/plate implants applied using indirect reduction techniques are successful in treating these challenging injury patterns. The insertion of PMMA beads at the time of definitive fixation was felt to reflect clinically important metaphyseal bone defects and was identified as a surrogate for bone loss. However, 35% of fractures with PMMA beads did not require subsequent bone grafts, suggesting that not all bone defects require subsequent bone grafting (Figure).

The radiographic appearance of posterior cortical contact strongly correlates with union and may obviate the need for staged bone grafting, despite the lack of anterior or lateral bone. Osseous presence in these areas suggests maintenance of the posterior soft tissue envelope critical for obtaining union. The maintenance of frontal and sagittal plane alignments also suggests that adequate early fracture stability is obtained. The ensuing bridging callus in the posterior region likely enhances fracture stability and considerably negates the
stresses subsequently incurred by the lateral implant.

**CONCLUSION**

Union rates of distal femur fractures, both open and closed, treated with Less Invasive Stabilization System plates range from 91% to 93%. To date, no investigation has isolated the treatment of open distal femur fractures treated with locked lateral plating applied in a minimally invasive fashion. The current study demonstrated that fixed angle screw/plate implants may decrease the need for staged bone grafting while maintaining alignment, even in situations with metaphyseal bone loss, provided that viable posterior and/or medial osseous fragments exist.

**REFERENCES**


**Figure:** Anteroposterior (A) and lateral (B) radiographs of a patient with an open distal femur fracture and a metaphyseal defect after plating and placement of beads. Follow-up anteroposterior (C) and lateral (D) radiographs showing that the patient healed without grafting. Note the presence of posterior cortical contact.