Administration of Distal Femur Fractures in Adults: An Overview of Options

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BACKGROUND

Supracondylar femur fractures are severe injuries that can be technically challenging to operatively treat. Although they account for less than 1% of all fractures and between 3% and 6% of femur fractures, their incidence is likely to increase with the rising geriatric populations and the increasing number of peri-prosthetic injuries. Injuries to the distal femur follow a bimodal distribution between geriatric low energy fractures and high-energy trauma. As with all fractures involving periarticular metaphyseal bone, treatment invariably includes understanding the fracture characteristics, careful preoperative planning, assessment of patient goals and health, bone quality, surgeon experience and implant selection.

In the early 1960s, most distal femur fractures were managed conservatively with fracture bracing and traction, achieving acceptable results in 67% to 90% of patients. However, with the advent of new surgical techniques and implants, the pendulum shifted from conservative management to surgical stabilization of these injuries.

Through historical review, Henderson and colleagues chronicled the increasing success rates with operative fixation from 52% to 54% in the 1960s, 73.5% to 75% in the 1970s, to 74% to 80% in the 1980s. Steady advances in our understanding of distal femoral anatomy and fracture biology have heralded various implant designs that further optimized successful treatment of these injuries. These modalities, each with their own merits and drawbacks, range broadly from external fixation, fixed-angle devices (blade or sliding barrel options), intramedullary nailing, arthroplasty, and distal femoral replacement (DFR) (Box 1).

The authors intend to review these modalities and examine their success and pitfalls to provide a primer for the current clinical care of adult supracondylar femur fractures.

ANATOMY AND CLASSIFICATION

The distal femur is descriptively divided into a supracondylar region encompassing the region between the meta-diaphyseal junction and the...
condyles and an intercondylar region that encompasses the condyles and articular surfaces. The periarticular/supracondylar region enjoys a better blood supply than that of the distal shaft, enabling adequate healing when stabilized. The normal anatomic axis of the femoral shaft is oriented between 6° and 11° of valgus in relation to the joint line (Fig. 1A). Restoration of this mechanical axis and prevention of varus collapse is a crucial factor in the success of distal femoral reconstruction and ultimate longevity of the joint. The medial and lateral cortices of the distal femur also taper anteriorly toward the midline at angles of approximately 25° and 10°, respectively (see Fig. 1B). This taper must be taken into account when selecting screw lengths and confirmed with internal rotation views to prevent hardware irritation from prominent screws medially. Knowledge of anatomy is crucial during placement of plates, which are often designed to be positioned along the anterior distal femur, approximating the border of the articular surface while avoiding intra-articular penetration of screws within the notch posteriorly or the trochlea anteriorly. Care must be taken during patient positioning and prep to allow for satisfactory imaging to be obtained intraoperatively in order to avoid such pitfalls. Other considerations during the preoperative setup include obesity, body habitus, other prostheses, and wounds.

The distal femur is spanned by several muscle groups that can create deformities across fractures. Depending on the fracture plane and comminution, the quadriceps typically cause shortening, whereas in the coronal plane varus/valgus deformity can be imparted by the adductors or iliotibial (IT) band. Additionally, the distal segment can be deformed by the two heads of the gastrocnemius, causing an apex posterior deformity best seen on lateral radiographs or in the form of a “paradoxic notch view” on an anteroposterior (AP) image.

The most commonly used classification system for distal femur fractures is the AO/Orthopedic Trauma Association (OTA) system (Fig. 2). Fractures are broadly classified into types A, B, and C corresponding to extra-articular, partial articular, and intra-articular injuries, respectively. They are further subclassified (1–3) based on pattern and degree of comminution. Type B1 involves sagittal splits of the lateral condyle; B2 involves sagittal splits of the medial condyle; B3 involves coronal patterns commonly known as Hoffa fractures. Type C fractures are divided into C1 (simple articular, simple metaphyseal), C2 (simple articular, multi-fragmentary metaphyseal), and C3 (multi-fragmentary). Careful scrutiny of radiographs and additional studies may be needed to accurately describe fracture patterns.

DIAGNOSIS AND IMAGING

Initial evaluation of patients begins with an accurate history and physical examination to identify the mechanism and time course of the injury. Identification of high-energy versus low-energy mechanism

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**Box 1**

**Treatment options**

- Splinting and casting
- Skin or skeletal traction
- External fixation
- Plate fixation (locked and unlocked)
- Intramedullary nail
- Arthroplasty/DFR

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**Fig. 1.** (A) Anatomic and mechanical axis of femur. (B) Dimensions of distal femur.
may also allow insight into the patients’ bone quality and general health condition. Swelling and soft tissue condition should be critically evaluated to identify effusions/hemarthrosis, compartment syndrome, and open fractures. A baseline neurovascular examination of both lower extremities can aid in the documentation of prior neurologic compromise or vascular insufficiency. If weak pulses are found, a Doppler probe should be used and ankle brachial index should be performed to aid in assessing possible arterial compromise.

Imaging studies should always begin with plain radiographs (AP and lateral) of the knee and the hip to rule out any additional trauma. If excessive shortening or deformity obscures initial radiographs, traction views can aid in the preoperative visualization. Although not always necessary in extra-articular supracondylar femur fractures, computed tomography (CT) scans can play a key role in identifying intercondylar extension in patients with inadequate radiographs or osteoporotic bone. Type B3 fractures or coronal plane Hoffa fractures of the posterior femoral condyle are prevalent in up to 38% of intercondylar fractures and may elude initial detection on orthogonal plain films. These injuries can often be open and involve both condyles, and evaluation with a CT scan is strongly recommended.

**MANAGEMENT**

Current treatment options broadly include conservative management (cast/splint, traction), external fixation, locked and unlocked plating, lateral fixed-angle device (blade or sliding barrel options), intramedullary nailing, and arthroplasty. Despite the myriad of techniques available, the primary goal of surgical treatment remains: restoration of the articular unit to the shaft and anatomic alignment while maintaining stability to enable early range of motion (ROM) and rehabilitation.

**NONOPERATIVE**

Although most distal femoral fractures tend to be operatively treated, there still exists a consistent role for conservative management. Indications include nondisplaced fracture, nonambulatory patients or spinal cord injury, unreconstructable injuries, or those patients with multiple comorbidities that preclude operative fixation. A study comparing operative versus conservative management of distal femur fractures in myelopathic, nonambulatory patients found a 90% union rate, with complications including skin and wound issues in patients treated conservatively and no wound complications in patients treated operatively. Surgeon experience and implant availability must also be taken into consideration when approaching such injuries.

Various methods of immobilization include long leg splints, casts, or skin/skeletal traction. Splinting or casting paired with non-weight-bearing restrictions must be maintained for 4 to 6 weeks with routine interval radiographs to monitor healing progress. Initial stabilization of supracondylar fractures may be performed with skin or Buck traction and may be converted to skeletal traction through the insertion of a proximal tibial traction pin. Balanced skeletal traction is advised in patients for whom traction will be definitive treatment, as it avoids excessive exertion of force through the skin and soft tissue layers. Regardless of modality, conservative management with prolonged immobilization has inherent complications: joint stiffness, decubitus ulcers, pulmonary complications, deep vein thrombosis, and deconditioning.

**SURGICAL APPROACHES**

Distal femur fractures can be operatively treated through minimally invasive submuscular techniques involving small lateral incisions or through conventional exposures performed anteriorly, laterally, or medially based on the fracture pattern and surgeon comfort. The workhorse approach proven in fractures involving the articular surface is the lateral para-patellar arthrotomy with varying degrees of proximal extension. The swashbuckler and mini swashbuckler approaches have been described, enumerating techniques to extend the laterally based arthrotomy proximally between the IT band and vastus lateralis by following the lateral intermuscular septum to expose the distal femur. Depending on the fracture pattern, a medial approach may also be used in conjunction to the arthrotomy to access the fracture for reduction or fixation purposes. This accessory approach may also be used to secure vertical or coronal fractures in type B injuries with interfragmentary screws if necessary. Retrograde intramedullary nailing requires astute knowledge of anatomy and selection of an optimal starting point. Many investigators agree that a small 3- to 4-cm arthrotomy positioned medial to the patellar tendon allows best access to the notch, because the patellar tendon and tibial tubercle are slightly laterally oriented structures.

**OPERATIVE STRATEGIES**

*External Fixation/Tensioned Ring Fixation*

In patients with severe soft tissue injury, application of a knee-spanning external fixator can allow
for temporization and implementation of damage control protocols. Careful planning of pin placement outside the zone of injury will reduce the risk of infection and maintain the integrity of the soft tissue for a staged formal surgical approach. Severe comminuted fractures can also be treated definitively with tensioned external fixation devices such as the Ilizarov fixator. Arazio and colleagues evaluated 14 complex fractures (type A and C) treated in this manner and found that union occurs around 16 weeks with a mean ROM of 105° at the knee. With the only complication being an infected nonunion, they concluded that the fixator is a safe option that provides adequate stability. Subsequently, Kumar and colleagues examined the outcomes of the Ilizarov fixator in open supracondylar fractures and found that union occurred much later at 39 weeks, with at least 4 cm of shortening noted in 40% of fractures and pin-track infections in 21% of patients. Clinical outcomes were also fraught with complaints of pain and loss of ROM.

**Open Reduction Internal Fixation with Fixed-Angle Blade Plate and Dynamic Condylar Screws**

The advent of the fixed-angle blade plate transformed the care of distal femur fractures by providing a construct with polyaxial stability and inherent rigidity. The early designs constituted an angled side plate that could be impacted into the distal femur and held rigidly in place by means of the precontoured region of the plate that lay along the metaphyseal flare of the distal femur. The angle of the blade was commonly 95°, and careful implantation ensured that length and alignment could be restored even in injuries with metaphyseal comminution. The drawbacks of this design include the large exposure needed, inadequate fixation in osteoporotic bone, and the inability to address coronal plane fractures. When compared with locked plates in a cadaveric biomechanical study, fixed-angle blade plates were a significantly weaker construct, tolerating less load to failure and resulting in more subsidence during cyclic stress.

The fixed-angle concept was further developed into a sliding screw with a side-plate design to allow compression between intercondylar splits. This implant, commonly known as the dynamic condylar screw (DCS), was rapidly incorporated for its ease of application and smaller exposure. Drawbacks are similar to those of the fixed-angle blade plates in that the DCS remains incapable of securing coronal fractures and incurs large amounts of bone loss during insertion of the screw. Additionally, biomechanical studies showed that DCS implants bent at the plate-barrel junction when cyclically loaded causing varus fracture deformity. When compared with locked plates, the DCS was also noted to be weaker in axial stiffness and cyclic loading but similar in torsional stiffness. Although fixed-angle blade plates and DCS implants have both had satisfactory results in long-term follow-up with 82% and 81% good to excellent results, respectively, other options should also be considered.

**Open Reduction Internal Fixation with Plate Fixation**

When the decision has been made for operative intervention, knowledge of the fracture pattern and the use of the AO classification can help determine the optimal use of plate fixation. Broadly, type A fractures with a simple pattern should be plated in compression, whereas those with comminution should be bridged, ensuring uniform callus formation. Type B fractures typically require compression across the fracture site or a buttress-type construct (Fig. 3). Low-profile lag screw placement perpendicular to the fracture is imperative, especially in Hoffa-type fractures. Type C fractures require anatomic reduction of the articular surface in addition to attaining appropriate anatomic alignment and rotation (Fig. 4).

With the advances in options for plate osteosynthesis and screw design, precontoured locking plates have quickly become the most commonly used implant in modern orthopedics. Several minimally invasive plating systems are commercially available that can be applied submuscularly through small incisions with the use of radiolucent outriggers and guides. Although locking plate technology allows for the preservation of periosteal blood supply by circumventing a tight plate-bone interface, they also inherently create very stiff constructs that have been known to suppress fracture healing. Granted, techniques that confer added rigidity may in some instances positively influence bone union; making a construct too rigid can conversely be detrimental to healing callus formation. Biological motion across a fracture site has long been known to be both stimulatory and necessary for healing across comminuted segments of bone and remains the premise for bridge plating techniques.

Important considerations when plating include the material composition of the plates. Given that stainless steel is roughly twice as rigid as a comparable titanium plate, the use of titanium and associated alloys confers more flexibility and
aids in the formation of more callus.\textsuperscript{19} Screw sele-
ction and placement also play a significant role in the biomechanics of the planned construct. Placement of locking screws at the terminal ends of the plate has been correlated with increasing thigh pain\textsuperscript{11,21} and risk of periprosthetic fractures due to excess stiffness and stress concentra-
tion.\textsuperscript{22} Although omission of screws in the holes immediately adjacent to the fracture site has been recommended in the past to increase the bridging zone and reduce stiffness,\textsuperscript{23} this technique has not been consistently shown to be suffi-
cient in modern locked plate designs.\textsuperscript{19} Plates with polyaxial screw capability allow the surgeon to apply screws in various angles with the use of locking caps, providing fixed-angle stability. A biomechanical comparison showed that these configurations are mechanically sound and super-
ior, with torsional stiffness and load to failure both greater than their uniaxial/traditional counterparts.\textsuperscript{24}

In addition to techniques, numerous implants have also been developed to impart varying degrees of motion at the fracture site, allowing a more physiologic healing environment. Considering the necessary balance between stability and fracture motion, new concepts such as far cortical locking (FCL) screws were introduced that combine locking technology with elastic materials to yield a dynamic plating solution. Using flexible locked screws that engage only the far diaphyseal cortex, symmetric compression is al-
lowed across the entire fracture when loaded. The sliding near cortex forms a motion envelope enabling symmetric callus formation and axial motion around the fracture, while evenly distributing the load between FCL screws, preventing stress risers.\textsuperscript{19,25} A prospective observational study

Fig. 3. (A) Type B fracture, AP view. (B) Type B fracture, oblique view. (C) Type B fracture, coronal CT. (D) Type B frac-
ture; buttress plate and interfragmentary screw fixation, AP view. (E) Type B fracture; after fixation, lateral view.
Fig. 4. (A) Type C fracture, AP view. (B) Type C fracture, lateral view. (C) Type C fracture, 3-dimensional CT reconstruction. (D) Type C fracture, intraoperative AP view. (E) Type C fracture, intraoperative lateral view. (F) Type C fracture; after fixation, AP view. (G) Type C fracture; after fixation, lateral view.
conducted on a cohort of 31 patients found that on average between 3 and 5 FCL screws were used in the shaft (125 total screws), yet there was no screw breakage and only 2 patients required revision surgery. Complications included varus collapse, infection, and hypertrophic nonunion. Based on these findings, the investigators asserted that the use of FCL screws is a safe and effective method to stabilize fractures of the distal femur.

Locked lateral plate constructs, although biologically friendly, may not always impart adequate stability in light of severe medial comminution. Composite plating techniques, such as medial endosteal plate augmentation, allows for bicolumnar support in poor bone through a single lateral incision. Patients with extensive medial compromise or soft tissue injury would be ideal candidates for the insertion of a surrogate medial cortex, without performing a formal medial approach. A biomechanical study found that the insertion of an interlocked medial endosteal plate to augment a lateral plate imparted a significant increase in rigidity (decreased motion in torsion and axial loading) when compared with a lateral buttress plate alone. The applicability of this technique is limited to a few unstable fracture types, with potential disadvantages including prolonged surgical time, blood loss, and difficulty with future implant removal or arthroplasty.

### Retrograde Intramedullary Nailing

Improvement in implant design and insertion techniques has gradually led to the increase in applications for intramedullary nails. With careful consideration of fracture reduction, starting point, and reaming, nailing options offer a relatively soft-tissue friendly modality of fracture care performed through a small incision. Additionally, the use of an intramedullary device can offer earlier weight bearing and motion in the injured extremity because the implant can be load sharing. This advantage prevents the occurrence of deconditioning and complications due to prolonged immobilization in older patients or patients with polytrauma (Fig. 5).

As with all nailing techniques, it is paramount that the desired fracture reduction is obtained before reaming and nail insertion. Various techniques may be used to decrease deformity, including sterile triangles and bumps, intraoperative traction or distal femoral distractor, small incisions to apply clamps or bone hooks, application of Schanz pin joysticks, blocking screws, and so forth. Careful radiographic assessment is critical at each step to ensure proper rotation and alignment, which may be readily compared with images of the contralateral limb and the profile of the lesser trochanter of the injured limb. Fractures with intraarticular extension may be safely stabilized with nails once the articular block has been reconstructed with interfragmentary screws. Of course, this must be done in consideration with the nail’s intended trajectory as well as placement of interlocking screws.

Once the fracture is adequately reduced and the intended lag screws have been secured, the process of nail insertion can be planned. The starting point should be found fluoroscopically just anterior to the distal extent of the Blumensaat line on the lateral view. The guide wire is inserted in the intercondylar notch, just anterior to the footprint of the posterior cruciate ligament on the femur. Using soft-tissue friendly methods, the notch may be opened and reaming may be initiated after ensuring secure reduction. Preoperative and intraoperative planning with radiographs and fluoroscopy by placing nail templates beside the fracture can aid in the planning of proposed lag screws in conjunction with interlocking screws. The length of the nail must also be considered, ensuring that there are enough interlocking slots above and below the fracture, for adequate fixation while also confirming that the nail does not protrude within the joint. Long nails are often recommended as they prevent periprosthetic fractures at the nail tip and increase the working length of the nail (enabling biologic motion) and to obtain an isthmic fit for optimal stability and load distribution. A recent biomechanical study comparing the combination of a retrograde nail and locking plate against either of the implants in isolation found that the combination was more resistant in axial, torsional, and load-to-failure tests. When compared with dynamic condylar screws and locking condylar plates, intramedullary nails demonstrated 47.5% and 77.0% greater axial stability, respectively, and were found to have less micromotion. A long-term study of 23 fractures with around 80 months of follow-up comparing plates with nails showed that nails required less bone grafting (67% vs 9%) and had lower malunion rates (42% vs 0%), respectively.

### Arthroplasty and Distal Femoral Replacement

Fractures in elderly patients can be challenging when there is extensive comminution of the articular surface. Despite anatomic reconstruction and rehabilitation, posttraumatic arthritis and knee pain are complaints that commonly arise in addition to any baseline osteoarthritis. Often, the
Fig. 5. (A, B) Preoperative intramedullary nailing. (C, D) Intraoperative intramedullary nailing. (E, F) Postoperative intramedullary nailing.
treatment algorithm overlooks primary arthroplasty and DFR as a treatment option in younger patients; but it can be a valuable alternative in older patients with baseline osteoarthritis, metaphyseal bone loss, and extensive intra-articular involvement.

Several investigators have proposed arthroplasty as a primary means of treating distal femoral injuries and avoiding issues of nonunion while allowing early weight bearing. Careful preoperative planning and imaging of the contralateral limb are important to gauge and use as a template for implants. Based on the fracture pattern, implant options can include unstemmed total knee arthroplasty (TKA) for simple fractures, stemmed TKA for fractures with metaphyseal extension, hinged prostheses for injuries likely to have ligamentous instability, and DFR for fractures with extensive metaphyseal comminution and bone loss. All the aforementioned prostheses may be augmented with the adjunctive use of interfragmentary screws, cabled and cement when necessary for stability. Bell and colleagues reported excellent results in a series of 14 patients with supracondylar or intercondylar femur fractures treated with primary TKA. Rosen and colleagues followed a series of 24 patients who underwent primary DFR TKA for 11 months, with 71% of them returning to their preinjury level of ambulation. This group of patients had an average range of motion from 1° to 103° and did not have any surgical complications. In a recent study in 2013, Choi and colleagues evaluated the use of TKA in 8 patients with distal femur fractures and underlying osteoarthritis. The investigators used the medial pivot knee model with and without the use of a stem depending on the fracture type. They found that all patients united around 15 weeks with good clinical results (Fig. 6). They concluded that TKA combined with limited internal fixation is a good option for patients with simple fracture types and adequate bone stock. Arthroplasty has also been studied as a salvage option in the event of failed internal fixation or nonunion. A series of 17 patients had TKA performed and were followed for 5 years, with significant improvements in their Knee Society score and mean functional scores. Although the procedure provided reliable pain relief in most patients, the investigators remarked that the surgeries were difficult and fraught with complications.

**SUMMARY**

With the increasing active and geriatric population, supracondylar femur fractures will continue to be a common occurrence. A thorough scrutiny of patients and their long-term health and goals will aid and guide in the treatment of their injury. The results of operative fixation have consistently

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**Fig. 6.** (A, B) Preoperative primary TKA. (C, D) Postoperative primary stemmed TKA augmented with cerclage wires and screws. (*From* Choi NY, Sohn JM, Cho SG, et al. Primary total knee arthroplasty for simple distal femoral fractures in elderly patients with knee osteoarthritis. Knee Surg Relat Res 2013;25(3):141–6; with permission.)
improved and continue to have a decreasing biological impact on patients using minimally invasive techniques and soft-tissue friendly strategies. As with all injuries, careful planning and consideration of the fracture biomechanics and biology render even the most complex supracondylar femur fracture a treatable malady.

REFERENCES


