

# Current Concepts in Fractures of the Distal Femur

## Současný pohled na zlomeniny dolního konce stehenní kosti

B.-C. LINK, R. BABST

Department of Trauma Surgery, Cantonal Hospital Lucerne, Lucerne, Switzerland

### SUMMARY

This paper describes current treatment strategies of distal femoral fractures as well as their evidence based rationale. The treatment of distal femoral fractures has improved with the evolution of plating and nailing technologies. The commonly selected surgical approaches are outlined and surgical treatment techniques including both internal and external fixation are discussed.

### INTRODUCTION

In recent years, the treatment of distal femoral fractures has evolved although these fractures remain complex to treat and carry an inconsistent prognosis. With this paper we will try to elucidate current treatment strategies as well as their evidence based rationale. The commonly selected surgical approaches will be outlined and surgical treatment techniques including both internal and external fixation are discussed. Moreover, we will review the present literature and make an effort deducing therapy recommendations.

### INCIDENCE/PATHOAETIOLOGY

An estimated 6% of all fractures of the femur account for the distal part of the bone (22, 32). The fractures occur in a bimodal distribution. One group including patients below 40 years of age, predominantly males, sustaining high-energy trauma such as traffic accident or a fall from heights. The other group is consisting of patients >50 years, predominantly females, with osteoporosis, who sustain relatively low energy trauma (32). In both instances, axial load to the leg is the most com-

mon mechanism of injury. Less frequently rotation forces lead to distal femoral fractures (32).

Almost 60% of distal femoral fractures occur in the age group >50. The osteoporosis within this group may pose problems for fixation (22). Associated meniscal or ligamentous damage following distal femoral fractures has been described, whilst the incidence of neurovascular injury remains rare (4). Approximately 0.2% of these fractures are associated with damage of the femoral or popliteal artery (47). Nevertheless, because of the low quantity and quality of collaterals, vascular injury threatens the vitality of the whole extremity and therefore has to be carefully ruled out.

### ANATOMICAL IMPLICATIONS

Distal femoral fractures engage the femoral metaphysis and the condyles. The anatomical axis of the femur runs about 8-10 degrees laterally from the loading axis, which is connecting the centre of the femoral head with the middle of the talar joint line. Therefore, axial load of the leg (e.g. standing) results in bending stress of the femur that is mainly compensated by the iliotibial tract (12).

The appreciation of deforming forces involved is critical for adequate surgical management. The characteristic deformity is shortening of the fracture with varus and extension of the distal articular segment (48). Shortening is caused by the quadriceps and hamstring muscles. The varus and extension deformities are the result of unopposed pulling of the hip adductors and gastrocnemius muscles respectively. All efforts reducing and retaining distal femoral fractures must respect and adapt to this deformity forces (47).

However, a critical aspect of the femoral anatomy represents the shape of the articular block and the anterior bow of the femoral shaft. On axial section, the distal articular segment has a trapezoidal shape. The medial and lateral edges of the condyles are converging ventrally for about 15-25°, and the ventral and dorsal joint lines are not parallel either. Consequently, the length of the introduced implants has to be critically emphasised considering this special shape. Unawareness of this anatomy may lead to anterior displacement, medialisation, and external rotation of the femoral condyles, articular penetration by implants, or excessive penetration of the medial cortex (11).

## ASSESSMENT

Careful consideration of the trauma mechanism, examination for associated injuries as well as evaluation of the fracture itself should be included in every initial patient assessment. High-energy trauma is frequently accompanied with concomitant skeletal injury as well as damage to soft tissues or solid organs. Exclusion of life and limb threatening concerns according to acute emergency protocols (e.g. ATLS) prior to management of the fracture are mandatory. The neurovascular status of the extremity should be vigilantly examined and documented. Initial documentation of the neurovascular status and continuous peri- and post-operative surveillance for signs of compartment syndrome or delayed presentation of an intimal arterial tear are mandatory to omit limb-threatening ischemia. In the setting of open fractures, early antibiotic coverage may help reducing infection rates. Grade I and II open fractures should be treated with preoperative dosing of prophylactic antibiotics for coverage of gram-positive organisms. In general, treatment should not exceed 24 hours. For Grade III open fractures, additional coverage for gram-negative bacteria is recommended and continued for 72 hours or until sufficient soft tissue coverage is achieved. (17) Open fracture wounds should be photo-documented and dressed sterile, and prophylactic tetanus immunisation should be given in the emergency department already.

In general, high-energy injuries with concomitant soft tissue compromise require prompt treatment, often including soft tissue debridement, compartment release, and initial joint bridging external fixation. Usually, this is followed by additional secondary imaging including CT for planning and subsequently delayed definitive operative treatment. Low energy traumas, in contrast can be dealt according to available resources.

AP and lateral x-rays are the standard radiological evaluation. Oblique x-ray views are dispensable if computerised tomography (CT) imaging is available. However, CT scanning including 3D reconstruction permits more detailed examination of the fracture patterns and should be obtained if complex or intra-articular fractures are assumed. Nork et al. examined 202 patients with fractures of the distal femur with intercondylar involvement and showed that 38% of fractures are including the condyles by coronal fracture extension (37). Eighty-five per cent of the coronal plane fractures involved the lateral condyle and 9% incorporated both condyles. In this study, plain radiographs alone did not identify 31% of the coronal plane fractures. Therefore the authors conclude that obtaining a preoperative CT scan is important, because identifying coronal plane fractures is critical for preoperative planning, with regard to surgical approach and implant selection. In polytraumatised patients with distal femoral fractures that are treated with temporary external fixation until definitive surgery may be performed, it is beneficial to obtain the CT scan after the knee-spanning external fixator is applied. The distraction and ligamento-taxis provided by the external fixator allows for easier visualisation of fragments and better appreciation of the personality of the fracture to allow adequate preoperative planning.

Magnetic resonance imaging (MRI) is helpful if relevant ligamentous or other soft tissue injuries are suspected. Isolated avulsion of the collateral ligaments should always raise suspicion of serious associated ligament injuries to the knee, and there may also be peroneal nerve, meniscal or chondral, injuries. If MRI has to be performed after temporary or definitive fixation, utilisation of non-ferromagnetic materials is recommended to ensure patient safety and image quality.

Vascular lesions threaten vitality of the whole extremity since quantity and quality of collateral circulation is limited. So if there is any concern regarding limb perfusion, it is of utmost importance to perform angiography, duplex ultrasonography, or perfusion CT, remembering that the presence of distal pulses does not exclude arterial injury.

## CLASSIFICATION

The Müller AO classification (35) is the most widely used system to categorise distal femoral fractures (Fig. 1). Neer et al. (36), Seinsheimer (45), and Egund and Kolmert (13) have proposed classification systems as well, but these did not prevail. Moreover the AO classification unanimously has gained acceptance for distal femoral fractures.

According to the common principles of the AO classification, type A fractures are extra-articular and type B fractures are partial articular, which means that parts of the articular surface remains in contact with the diaphysis. Type C fractures are complete articular fractures with detachment of both condyles from the diaphysis. The fracture types are further subdivided describing the degree of fragmentation and other, more detailed

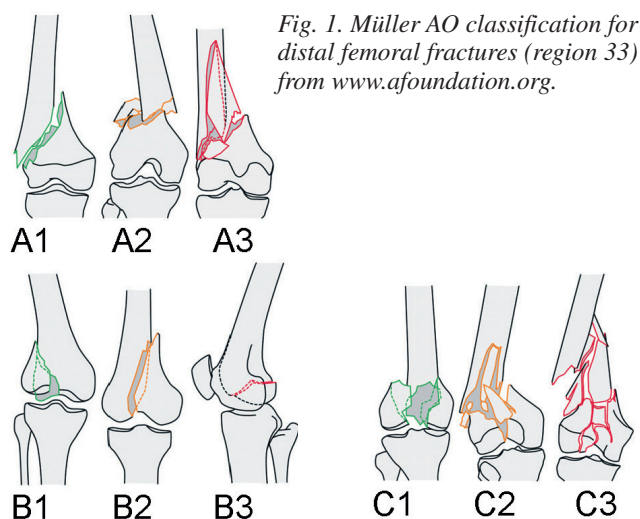


Fig. 1. Müller AO classification for distal femoral fractures (region 33) from [www.aofoundation.org](http://www.aofoundation.org).

characteristics. Further subdivision of type B fractures includes B1 (sagittal, lateral condyle), B2 (sagittal, medial condyle) and B3 (frontal, Hoffa type). Fracture type C is divided in C1 (articular simple, metaphyseal simple), C2 (articular simple, metaphyseal multifragmentary) and C3 (multifragmentary).

## PRINCIPLES OF MANAGEMENT

Non-operative treatment may be chosen in the rare situation of non- or minimal-displaced fractures in bedridden elderly patients not amendable to operative therapy. Conservative treatment consists of skeletal traction, or initial splinting and mobilisation with limited weight bearing. X-rays are typically obtained at weekly to biweekly intervals for the first 6 weeks warranting fracture reduction is maintained. Progressive weight bearing and joint mobilisation are initiated based on the clinical and radiographic succession of fracture healing.

In 1996 Butt et al. performed a randomised control trial evaluating operative versus conservative treatment for displaced distal femoral fractures in elderly patients. Patients were either randomised to operative treatment with a dynamic condylar screw ( $n=17$ ) or skeletal traction for 6 to 8 weeks followed by functional bracing ( $n=19$ ). Good or excellent results were obtained in 53% of the operatively treated patients versus 31% in the conservative group. The non-operative group had an increased risk for deep vein thrombosis (despite anticoagulation therapy), pulmonary and urinary tract infections, non-unions, mal-unions, and pin tract infections. Therefore, conservative treatment for displaced fractures is only recommended and considered for those patients who cannot tolerate surgery (8).

In dislocated fractures, displacement cannot be adequately corrected or retained with conservative measures. Operative treatment is indicated also for open fractures, and those associated with neurovascular injury. Treatment purposes comprise anatomical reduction of the articular surface, restoration of limb length, alignment and rotation, as well as adequate fixation, which allows for early postoperative knee range of motion and

patient mobilisation. Reconstruction of the articular surface and adequate restitution of axes, length and rotation are crucial to prevent late sequelae like osteoarthritis. Though, early knee mobilisation is of utmost importance to counteract permanent restriction of movement by muscle contracture as well as intra- or extra-articular adhesions.

Fractures with concomitant vascular injury need prompt provisional fixation to allow for vascular reconstruction that is followed by definitive osteosynthesis.

Nerve damage should trigger definitive or temporary osteosynthesis with primary revision of the nerve. However, temporary fixation always inherits the risk of compromising nerve sutures during secondary osteosynthesis. If microsurgical techniques are not available, nerve reconstruction may be performed secondary to fracture consolidation.

The timely management of menisco-ligamentous injuries is depending on the specified surgical approach. If arthrotomy is indicated to attend adequate treatment, meniscal or ligamentous damage may be managed during definitive osteosynthesis. Otherwise, menisco-ligamentous injuries may as well be treated secondary (44).

There are multiple alternatives for the definitive treatment of distal femoral fractures comprising of external fixation, intramedullary nailing, and plate osteosynthesis with either open reduction and internal fixation, or closed reduction and minimally invasive plate osteosynthesis (MIPO). Correspondingly, multiple different plating options are available including buttress plate fixation, fixed-angle devices like the angled blade plate (ABP) or the dynamic condylar screw (DCS), and locking plates. External fixation, however, as a temporary fixation device is indicated in polytraumatised patients, patients with massive soft tissue damage, open fractures, and situations with logistic or infrastructural limitations.

## SURGICAL APPROACH

The choice of surgical approach mainly depends on the type of fracture and implant. The supine position of the patient is preferred. Typically the knee is slightly flexed  $30^\circ$  by supporting it with paddings, which releases traction of the gastrocnemius muscle and prevents extension of the distal fragment. Draping free of both legs allows for intraoperative comparison of length, axes and rotation in relation to the well leg.

The lateral approach to the distal femur allows for visualisation, reduction and fixation of most of the fractures not involving the articular surface (type A) and often as well for simple articular fractures of the distal femur (Fig. 2). The approach relies on an atraumatic elevation of the vastus lateralis from the lateral aspect of the distal femur, and a lateral arthrotomy for joint access. Articular reduction and lateral plate application can both be achieved with the same approach. In addition, the approach may be extended proximally to display the entire length of the femoral shaft. Fractures of the medial femoral condyle and more complex fractures are



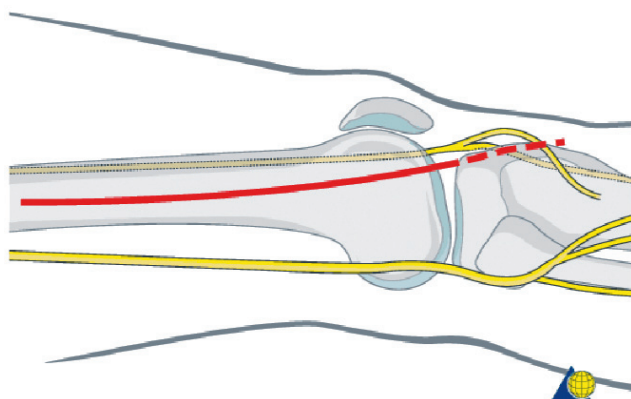


Fig. 2. Lateral approach to the distal femur.

better exposed with a lateral or rarely medial para-patellar approach that provides good view of the articular surface of the distal femur (Fig. 3). To gain full exposure to the knee joint, the patella has to be dislocated medially or laterally respectively through marginal longitudinal incision of the quadriceps tendon and extensor mechanism (Fig. 4).

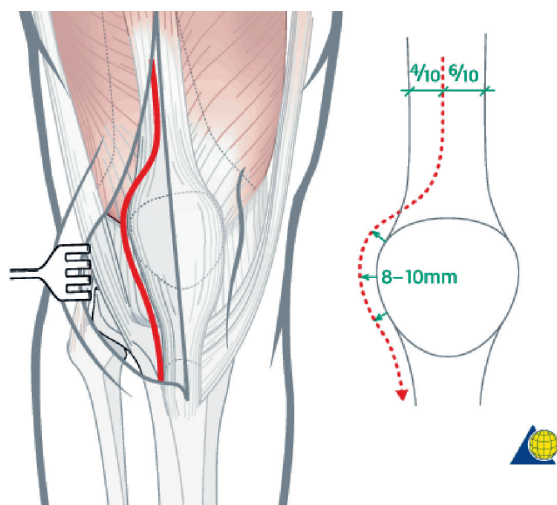


Fig. 3. Lateral para-patellar approach

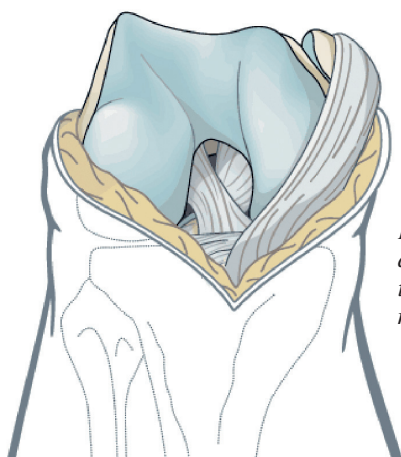


Fig. 4. Exposure of the articular surface after the patella is dislocated medially.

The lateral minimally invasive approach for plate osteosynthesis (MIPO) consists of a short lateral approach overriding the lateral condyle to the distal femur as well as a short lateral approach to the midshaft or proximal femur depending on plate length, and small stab incisions for direct reduction and percutaneous screw placement (Fig. 5 and 6).

A medial approach to the distal femur may be used to expose a medial distal femoral or Hoffa-type fractures.

A small transligamentous approach through the patellar tendon serves for insertion of a retrograde nail (Fig. 7). Two anatomical structures are at risk using this approach. The posterior cruciate ligament is the most important structure one should take care for. Furthermore, cartilage in the weight-bearing zone may be damaged.



Fig. 5. Checking plate length for minimally invasive plate osteosynthesis (MIPO) with the less invasive stabilisation system (LISS).

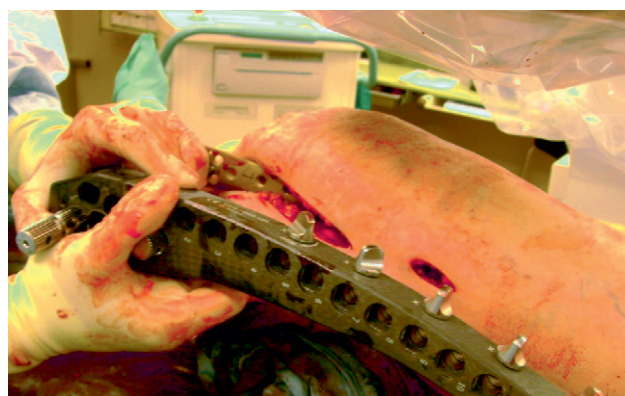


Fig. 6. Plate insertion with introducer and screw guide to perform the minimally invasive plate osteosynthesis (MIPO) with the less invasive stabilisation system (LISS).

Pin insertion for external fixation has to consider the condition of the soft-tissue envelope of the femoral shaft and the implant position for definitive fixation. In order to minimize the risk of subsequent pin-track infection, areas of extensive soft-tissue damage should be avoided. The major neurovascular structures are located medially and posteriorly. For that reason, the femur can safely be approached by pin insertion over the anterolateral and direct lateral regions of the femur.

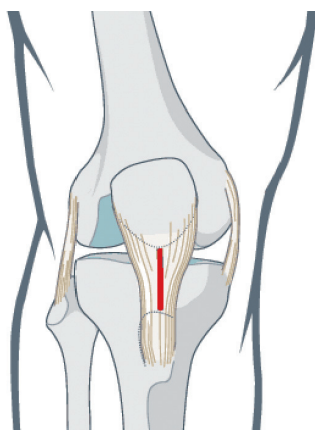


Fig. 7. Retrograde nailing approach.

## SURGICAL TACTICS

The surgical approach for type A fractures may be as minimal invasive and respect as much of the fracture biology as possible. This usually can be achieved by minimal invasive plate osteosynthesis (MIPO) or retrograde nailing of the fracture. Both approaches allow bridging the fracture zone with the respective implant. This stands in contrast to open reduction and internal fixation of intermediate fragments where blood supply and, consequently, the healing process may be impaired. However, if feasible, in simple fractures compression osteosynthesis should be favoured over bridging osteosynthesis since higher rates of non-unions have been reported for locked plating of simple fractures (28). Restoration of axial alignment, length and rotation of the fractured femur is minimising changes to the load-bearing axis of the lower limb as well as decreasing impact on the entire musculoskeletal system by gait alterations.

In type B femoral fractures open reduction of the affected femoral condyle is usually mandatory to achieve anatomic reduction. Lag screw osteosynthesis is the method of choice. In addition, an anti-glide plate may prevent secondary displacement, when the fracture extends more proximally.

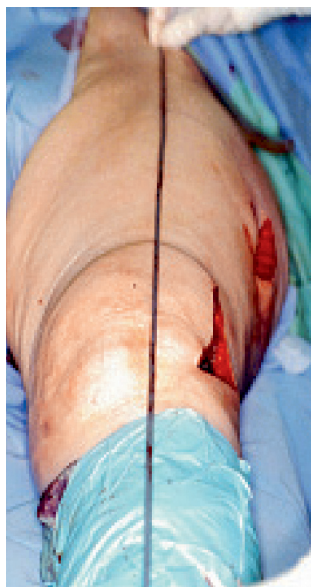


Fig. 8. The "cable method" utilises the diathermy cord to appraise the biomechanical axis of the leg.

Type C fractures usually need visualisation of the knee-joint to allow for anatomical reconstruction of the articular surface. Temporary k-wire fixation followed by screw osteosynthesis with lag screws of the femoral condyles should be carried out primarily. Stable and sufficient interfragmentary fixation is achieved with 3,5 mm screws. This screw dimension has the advantage not to hinder later plate application and screw fixation. Subsequently, the articular bloc is fixed to the femoral shaft. Here, as well, restoration of axial alignment, length and rotation of the limb is imperative. Several intraoperative measures have been well described to achieve these goals (e.g. cable method, width of cortex, visualisation of minor trochanter) and may be considered (19, 46) (Fig. 8).

In severely comminuted type C3 fractures a joint spanning external fixator may be a salvage procedure. The external fixator may be applied for several weeks trying to establish adequate conditions for later total knee arthroplasty (40).

## SURGICAL MANAGEMENT

### Conventional plating

Until the early 1960s studies were in favour of conservative treatment of distal femoral fractures and discouraged open reduction and internal fixation (ORIF) (36, 47). Later, in the 1970s and 1980s, several reports provided better results to support ORIF in fractures of the distal femur (34, 39, 43). Studies comparing ORIF with closed reduction and internal fixation (CRIF) directly, preferred ORIF with significant more good or excellent clinical results registered (81% open versus 42% closed, RR 0.5, 95% CI, 0.3–0.9) and a significantly reduced malunion rate (3% open versus 37% closed, RR 11.8, 95% CI, 1.6–88.0) (19) (46). However, ORIF aiming for absolute stability may require relevant dissection and can therefore lead to devascularisation of fracture fragments. Using this technique an increased risk of delayed union, non-union, infection, and implant failure was observed (24, 33, 48). To decrease these complications, concepts evolved applying indirect reduction techniques to restore length, rotation, and the mechanical axis without direct exposure of the fracture site and therefore maintaining the blood supply to the fracture region (Fig. 9). In the 1990s, the biological advantage of these indirect reduction techniques was demonstrated by several authors (5, 11, 25, 41). Bolhofner et al. (5) treated 57 patients with distal femoral fractures with either condylar buttress plate or angled blade plate using only indirect reduction techniques. The average time to fracture union and full weight bearing was 10.7 weeks with no non-unions or hardware failures reported. These results could be achieved although 11 patients with open fractures were included, and no bone grafting or dual plating had been used.

With further elaboration, the trend of indirect reduction led to the development of minimally invasive plate osteosynthesis (MIPO) (Fig. 5 and 6) (24). In a cadaveric study model, it could be demonstrated that passing a plate submuscularly under the vastus lateralis could



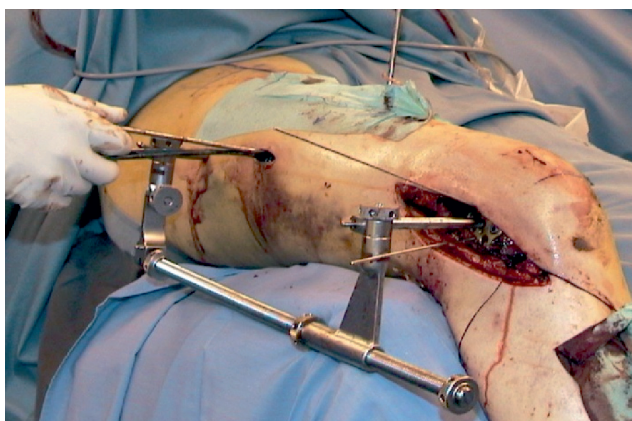


Fig. 9. Indirect reduction with the AO-Distractor.

preserve the perforating blood vessels. In addition the periosteal and medullary perfusion were superior when compared to the classic lateral approach to the femur, which raises the vastus lateralis and unpredictably disrupts the perforating arteries (53). This plating technique showed a decreased incidence of implant failure and infection, allowed for earlier fracture callus formation, and reduced the need for secondary bone grafting procedures in numerous clinical series (24, 53). Conversely, the lack of direct visualisation of the meta- and diaphyseal areas makes the procedure more technically demanding and obliges an increased use of fluoroscopy to ensure fracture reduction and correct limb alignment (Fig. 10 and 11). Several authors alluded to the signifi-



Fig. 10. Direct reduction in MIPO technique utilising the percutaneous reduction clamp for reduction against the plate.

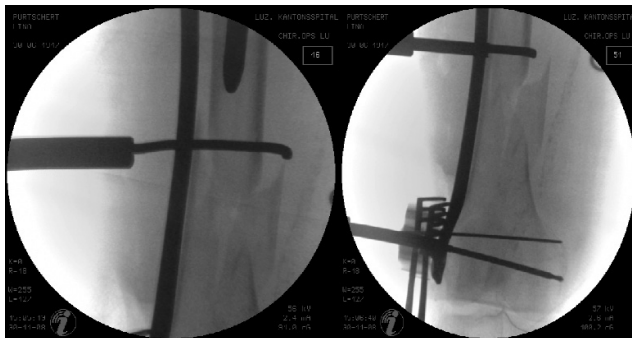


Fig. 11. Intraoperative fluoroscopy showing reduction against the plate with the percutaneous reduction clamp.

cance of a learning curve characterised by an elevated mal-union and revision rate (44) (53). Recently, the issue of mal-rotation following MIPO has been critically highlighted by Buckley et al. (6).

### Locked plating

Unlike conventional plate osteosynthesis, locking plates do not rely on friction at the bone-plate interface to create stability. Screws are secured to the plate by different locking mechanisms between the screw's head and screw hole to allow the screws to be fixed at a certain angle. Therefore, locking plates do not have to have direct contact to the bone, which allows for preservation of the periosteal blood supply (24).

Several studies have assessed the value of locked implants in treatment of distal femoral fractures (14, 23, 29, 50, 51). The commonly used implant in these series is the Less Invasive Stabilisation System (LISS) (Fig. 5 and 6). Zlowodzki et al. (53) analysed the outcome of these studies as part of a systematic literature review. Average non-union, fixation failure, deep infection, and secondary surgery rates were 5.5%, 4.9%, 2.1%, and 16.2% respectively. The technical errors that have been reported for fixation failure comprised of waiting too long to bone graft defects, allowing weight bearing too early, and placing the plate too anterior on the femoral shaft. Still, the LISS achieves very high rates of union (100%) and excellent clinical results (88%), based on the Lysholm score in multiple studies (9, 11, 42, 44).

Basically, two variations of locking plates exist. Unidirectional plating systems allow for locking screws to be placed in one orientation and typically use a threaded locking mechanism to create a fixed angle at the screw-plate interface (Fig. 12). Variable angle plating systems allow for the locking screw to be placed at different angles within certain limits based on the applied locking mechanism.

Continued development of locking plates led to the locking compression plate (LCP) that permits simultaneous application of locking screws as well as cortical screws in the same plate (11). This "hybrid"-fixation technique enables interfragmentary compression using eccentric drilling or lag screw application in simple fracture patterns, as well as the combination with locking



Fig. 12. Intraarticular distal femoral fracture (AO 33-C3) and its postoperative follow up after 8 months.

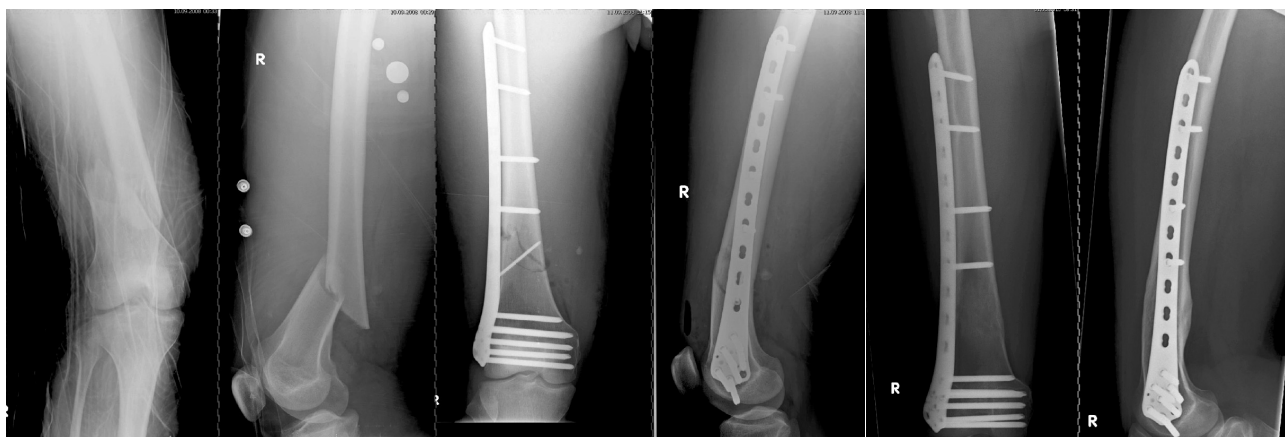


Fig. 13. The “hybrid” - fixation technique allows interfragmentary compression using excentric drilling or lag screw application in simple fracture patterns, as well as the combination with locking screws. Preoperative, postoperative and late x-ray controls. The lag screw had to be removed after 3 months since it was hindering further fracture healing. (38)

screws (Fig. 13) having the advantage of better fixation that theoretically increases screw pull-out strength in osteoporotic bone.

Hybrid fixation has been shown to be comparable to an all-locking screw technique in biomechanical studies. Gardner et al. (16) compared the biomechanical properties of hybrid plating, compression plating, and locked plating in an osteoporotic synthetic simple humeral shaft fracture model. Hybrid and locked plate constructs had equal torsional stiffness and cyclic loading in torsion. Freeman et al. (15) compared load to failure, axial stiffness, and screw extraction torque for distal femoral locking plates with locked or non-locked diaphyseal fixation in a non-osteoporotic and osteoporotic cadaveric supracondylar femur fracture gap model. Results demonstrated that locked diaphyseal fixation was superior in the osteoporotic model only.

To date, only one clinical study evaluated a plate with the ability to use hybrid fixation in the distal femur using the Locking Condylar Plate (condylar LCP, Synthes) (49). Forty-six patients with distal femoral fractures were treated with cannulated locking screws distally and bicortical non-locked screws for diaphyseal fixation using an open approach and indirect reduction technique. Twenty-five patients suffered from open fractures. Six of the 46 patients (13%) had implant failure. All of the failures occurred in type C3 fractures, with 4 of the 6 being open fractures. In this series with ORIF the authors concluded that the locking condylar plate should solely be used when conventional fixed-angle devices like the angled blade plate (ABP) cannot be positioned. Furthermore, they recommended accurate fracture reduction, fixation along with judicious primary bone grafting, and protected weight bearing to decrease the risk of implant failure with locking plates.

Multiple biomechanical studies have compared locking plates and conventional fixed-angle implants like the ABP (angled blade plate) or the DCS (Distal Femoral Plate) in distal femoral fracture models (21, 31, 54, 55). All of these studies reveal that locking plates with

unicortical or bicortical diaphyseal fixation have adequate axial stiffness but more elasticity when compared to conventional fixed-angle implants. Although they have less torsional stiffness, the studies that evaluated torsional stiffness have shown that the distal fixation in locked implants is typically maintained while conventional fixed-angle implants have a higher rate of distal cut-out from the femoral condyles (11).

### Intramedullary nailing

Fixation by intramedullary nailing has been recommended for type A fractures with intact distal femur to allow interlocking (Fig. 14). Although both ante- and retrograde nailing have successfully been applied in the treatment of type C1 and 2 fractures (7, 27), antegrade nailing has not prevailed. The greater number of distal fixation options available with retrograde nails resulted in their preferential utilisation in clinical practice. As with MIPO plating of distal femur fractures, indirect fracture reduction and a minimally invasive approach were adopted for nailing as well. Henry et al. (20) compared open versus percutaneous reduction techniques for retrograde nailing of distal femoral fractures. The authors were able to show improved postoperative knee function with decreased operative time, blood loss, bone grafting, and non-union rates without differences in malunion rate using the percutaneous approach. In a review, for retrograde nailing in distal femoral fractures Zlowodzki et al. (53) reported an average non-union rate of 5.3%, fixation failure rate of 3.2%, deep infection rate of 0.4%, and a 24.2% secondary procedure rate. Even in open fractures with or without articular involvement, retrograde nailing permitted early knee joint rehabilitation without an increased risk of septic arthritis (10). Generally, functional outcomes have been shown to correlate with patient age and the severity of the initial injury (27). In elderly patients, limited weight bearing is recommended until callus formation is seen to avoid fixation failure (3, 26). Complications related to retrograde nailing include



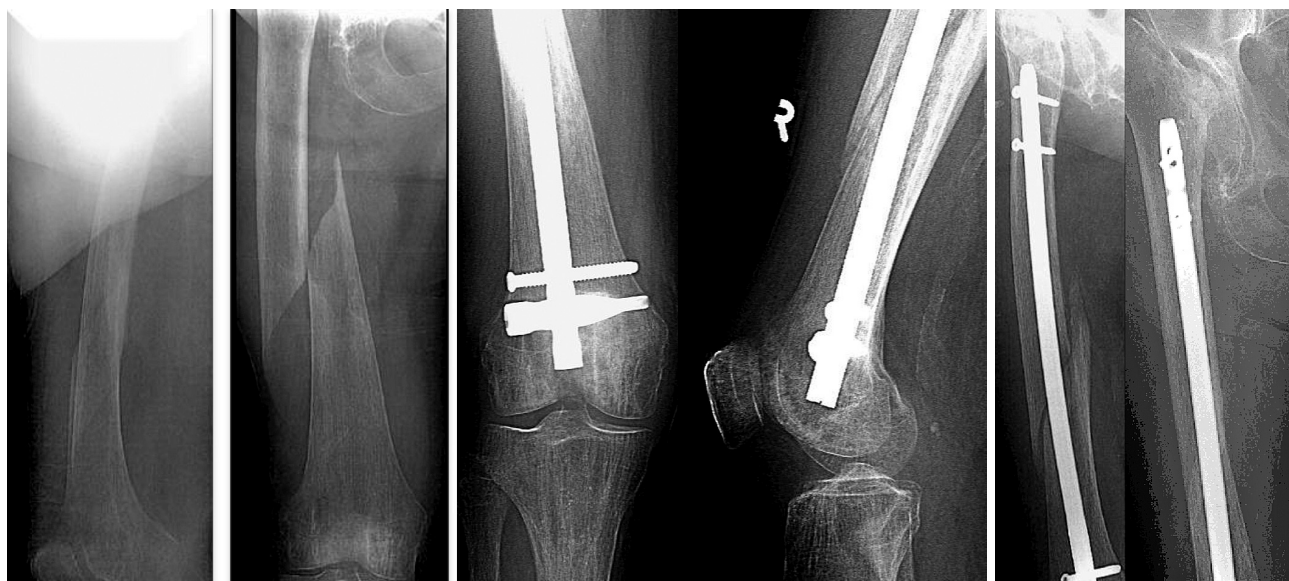


Fig. 14. Distal (or retrograde) femoral nail in a simple fracture in a patient with Girdlestone situation of the proximal femur. Day of accident and 6 weeks following osteosynthesis.

anterior knee pain, injury to the deep femoral artery with proximal locking, iatrogenic fracture of the femoral shaft, stress fracture above the implant, fatigue failure of the nail, intra-articular impingement of the nail due to inadequate entry point of the distal interlocking bolt, and varus malalignment requiring osteotomy correction (3, 10, 11, 26, 53).

Antegrade nailing in distal femoral fractures has been reserved for type A with fracture lines > 5 cm proximal to the articular surface to allow for adequate distal fixation. Benefits of antegrade intramedullary fixations include using a load-sharing device, decreasing surgical dissection of the fracture, and avoiding a large open arthrotomy (11). The systematic review of Zlowodzki et al. (53) revealed a non-union rate of 8.3%, 3.7% rate of fixation failure, 0.9% infection rate, and 23.1% rate of secondary procedures for antegrade nailing of distal femoral fractures.

Two studies, one a randomised trial and the other a prospective cohort study (18, 52), compared intramedullary nailing with plate fixation in distal femoral fractures. Union was high in both the plate group (84.6%) and the nail group (90.0%) without a statistically significant difference. With reference to complications, deep infections, knee range of motion, and time to union, nails appeared to be associated with better outcome, but this was not statistically significant. Likewise, Markmiller et al. (29) demonstrated in a non-randomised study that LISS and the distal femoral nail achieved both high rates of union and very good clinical results. Statistically significant differences in blood loss, mean operative time, and length of hospital stay were noted preferring the nail. In a prospective cohort study comparing mini open dynamic condylar screw versus supracondylar intramedullary nail, complications and time to union did not differ.

However, the systematic review of Zlowodzki et al. (53) was able to demonstrate that fractures treated by retrograde nailing tend to be less serious than those receiving plate osteosynthesis.

### External fixator

External fixation is most commonly used as a temporary joint spanning device (Fig. 15). It is typically employed for patients suffering from open fractures, bone loss, significant comminution, vascular injury, or

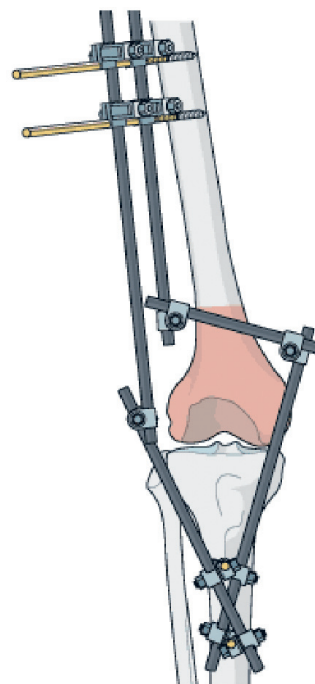


Fig. 15. External fixator used as temporary device. During definitive osteosynthesis it facilitates indirect reduction.



extensive soft tissue damage. Advantages described for external fixators comprise of less disruption of the blood supply to fracture fragments, decreased blood loss and length of surgery. Monolateral external fixations without spanning the knee as well as circular or ring fixators have been most commonly used (1, 2, 30).

Complications associated with the use of external fixation for definitive treatment of distal femoral fractures involve osteomyelitis, pin tract infection, septic arthritis, loss of reduction, delayed union or non-union requiring bone grafting, and limited knee motion through arthrofibrosis (30, 55). Time to bony union has been reported to require up to an average of 25 weeks (1). Zlowodzki et al. (53) reported an average 7.2% non-union rate, a 1.5% rate of fixation failure, a 4.3% rate of deep infection, and a 30.6% rate of secondary surgical procedures for treatment of distal femoral fractures with external fixation. However, all studies reporting on external fixation have been small case and mostly single surgeon series.

In conclusion, of all treatment options reported minimal invasive plate osteosynthesis (MIPO) or distal femoral nailing seems to prevail some pivotal advantages and should be preferentially applied. Locking plates (condylar LCP and LISS) may be used for all fracture types, whereas the distal femoral nail has limited indications in comminuted C2 and C3 fractures. Overall, DCS offers no advantages compared to locking plates and is not recommended for type C2 and C3 fractures.

## PROGNOSIS

The prognosis of distal femoral fractures is depending on the fracture type. Type A and B fractures imply a more favourable prognosis than type C fractures. Involvement of the articular surface of the knee affects knee flexion, stability, and overall patient satisfaction.

Surgeons with increased experience may significantly reduce the risk of revision surgery. (53)

## CONCLUSION

The treatment of distal femoral fractures has improved with the evolution of plating and nailing technologies. Minimal invasive procedures hold biological advantages as the incidence of delayed or non-union, infection, and the need for bone grafting are significantly decreased. However, MIPO inherits the disadvantage of a potentially higher mal-union rate and is technically demanding. The prognosis, though, seems to be less depended on the implant than on the type of fracture.

## References

1. ALI, F., SALEH, M.: Treatment of isolated complex distal femoral fractures by external fixation. *Injury*, 31: 139–146., 2000.
2. ARAZI, M., MEMIK, R., OGÜN, T. C., YEL, M.: Ilizarov external fixation for severely comminuted supracondylar and intercondylar fractures of the distal femur. *J. Bone Jt Surg.* 83-B: 663–667, 2001.
3. ARMSTRONG, R., MILLIREN, A., SCHRANTZ, W., ZELIGER, K.: Retrograde interlocked intramedullary nailing of supracondylar distal femur fractures in an average 76-year-old patient population. *Orthopedics*, 26: 627–629, 2003.
4. AUFFARTH, A., BOGNER, R., KOLLER, H., TAUBER, M., MAYER, M., RESCH, H., et al.: How severe are initially undetected injuries to the knee accompanying a femoral shaft fracture? *J. Trauma*, 66: 1398–1401, 2009.
5. BOLHOFNER, B. R., CARMEN, B., CLIFFORD, P.: The results of open reduction and Internal fixation of distal femur fractures using a biologic (indirect) reduction technique. *J. Orthop. Trauma*, 10: 372–377, 1996.
6. BUCKLEY, R., MOHANTY, K., MALISH, D.: Lower limb malrotation following MIPO technique of distal femoral and proximal tibial fractures. *Injury*, 42: 194–199, 2011.
7. BUTLER, M. S., BRUMBACK, R. J., ELLISON, T. S., POKA, A., BATHON, G. H., BURGESS, A. R.: Interlocking intramedullary nailing for ipsilateral fractures of the femoral shaft and distal part of the femur. *J. Bone Jt Surg.*, 73-A: 1492–1502, 1991.
8. BUTT, M. S., KRIKLER, S. J., ALI, M. S.: Displaced fractures of the distal femur in elderly patients. Operative versus non-operative treatment. *J. Bone Jt Surg.*, 78-B: 110–114, 1996.
9. BUTTON, G., WOLINSKY, P., HAK, D.: Failure of less invasive stabilization system plates in the distal femur: a report of four cases. *J. Orthop. Trauma*, 18: 565–570, 2004.
10. CIEŚLIK, P., PIEKARCZYK, P., MARCZYŃSKI, W.: Results of retrograde intramedullary nailing for distal femoral fractures—own experience. *Ortop. Traumatol. Rehabil.*, 9: 612–617, 2007.
11. CRIST, B. D., DELLA ROCCA, G. J., MURTHA, Y. M.: Treatment of acute distal femur fractures. *Orthopedics*, 31: 681–690, 2008.
12. DÁVID, A.: Distale Femurfrakturen. *Orthopädie und Unfallchirurgie update*, (1): 9–32, 2006.
13. EGUND, N., KOLMERT, L.: Deformities, gonarthrosis and function after distal femoral fractures. *Acta Orthop. Scand.*, 53: 963–974, 1982.
14. FANKHAUSER, F., GRUBER, G., SCHIPPINGER, G., BOLDIN, C., HOFER, H. P., GRECHENIG, W., et al.: Minimal-invasive treatment of distal femoral fractures with the LISS (Less Invasive Stabilization System): a prospective study of 30 fractures with a follow up of 20 months. *Acta Orthop. Scand.*, 75: 56–60, 2004.
15. FREEMAN, A. L., TORNETTA, P., SCHMIDT, A., BECHTOLD, J., RICCI, W., FLEMING, M.: How much do locked screws add to the fixation of “hybrid” plate constructs in osteoporotic bone? *J. Orthop. Trauma*, 24: 163–169, 2010.
16. GARDNER, M. J., GRIFFITH, M. H., DEMETRAKOPOULOS, D., BROPHY, R. H., GROSE, A., HELFET, D. L., et al.: Hybrid locked plating of osteoporotic fractures of the humerus. *J. Bone Jt Surg.*, 88-A: 1962–1967, 2006.
17. GILLESPIE, W. J., WALENKAMP, G. H.: Antibiotic prophylaxis for surgery for proximal femoral and other closed long bone fractures. *Cochrane Database Syst. Rev.*, 3: CD000244, 2010.
18. HARTIN, N. L., HARRIS, I., HAZRATWALA, K.: Retrograde nailing versus fixed-angle blade plating for supracondylar femoral fractures: a randomized controlled trial. *ANZ J. Surg.*, 76: 290–294, 2006.
19. HEALY, W. L., BROOKER, A. F.: Distal femoral fractures. Comparison of open and closed methods of treatment. *Clin. Orthop. Relat. Res.*, 174: 166–171., 1983.
20. HENRY, S. L.: Supracondylar femur fractures treated percutaneously. *Clin. Orthop. Relat. Res.*, 375: 51–59, 2000.
21. HIGGINS, T. F., PITTMAN, G., HINES, J., BACHUS, K. N.: Biomechanical analysis of distal femur fracture fixation: fixed-angle screw-plate construct versus condylar blade plate. *J. Orthop. Trauma*, 21: 43–46, 2007.

22. KOLMERT, L., WULFF, K.: Epidemiology and treatment of distal femoral fractures in adults. *Acta Orthop. Scand.*, 53: 957–962, 1982.
23. KREGOR, P. J., STANNARD, J. A., ZLOWODZKI, M., COLE, P. A.: Treatment of distal femur fractures using the less invasive stabilization system: surgical experience and early clinical results in 103 fractures. *J. Orthop. Trauma*, 18: 509–520, 2004.
24. KRETTEK, C., MÜLLER, M., MICLAU, T.: Evolution of minimally invasive plate osteosynthesis (MIPO) in the femur. *Injury*, 32(Suppl. 3): SC14–23, 2001.
25. KRETTEK, C., SCHANDELMAIER, P., MICLAU, T., TSCHERNE, H.: Minimally invasive percutaneous plate osteosynthesis (MIPPO) using the DCS in proximal and distal femoral fractures. *Injury*, 28(Suppl. 1): A20–30, 1997.
26. KUMAR, A., JASANI, V., BUTT, M. S.: Management of distal femoral fractures in elderly patients using retrograde titanium supracondylar nails. *Injury*, 31: 169–173, 2000.
27. LEUNG, K. S., SHEN, W. Y., SO, W. S., MUI, L. T., GROSSE, A.: Interlocking intramedullary nailing for supracondylar and intercondylar fractures of the distal part of the femur. *J. Bone Jt Surg.*, 73-A: 332–340, 1991.
28. LIU, F., TAO, R., CAO, Y., WANG, Y., ZHOU, Z., WANG, H., et al.: The role of LISS (less invasive stabilisation system) in the treatment of peri-knee fractures. *Injury*, 40: 1187–1194, 2009.
29. MARKMILLER, M., KONRAD, G., SÜDKAMP, N.: Femur-LISS and distal femoral nail for fixation of distal femoral fractures: are there differences in outcome and complications? *Clin. Orthop. Relat. Res.*, 426: 252–257, 2004.
30. MARSH, J. L., JANSEN, H., YOONG, H. K., FOUND, E. M.: Supracondylar fractures of the femur treated by external fixation. *J. Orthop. Trauma*, 11: 405–410, discussion 411, 1997.
31. MARTI, A., FANKHAUSER, C., FRENK, A., CORDEY, J., GAS-SER, B.: Biomechanical evaluation of the less invasive stabilization system for the internal fixation of distal femur fractures. *J. Orthop. Trauma*, 15: 482–487, 2001.
32. MARTINET, O., CORDEY, J., HARDER, Y., MAIER, A., BÜHLER, M., BARRAUD, G. E.: The epidemiology of fractures of the distal femur. *Injury*, 31(Suppl. 3): C62–63, 2000.
33. MAST, J., JAKOB, R., GANZ, R.: Planning and Reduction Technique in Fracture Surgery. Springer; 1989.
34. MIZE, R. D., BUCHOLZ, R. W., GROGAN, D. P.: Surgical treatment of displaced, comminuted fractures of the distal end of the femur. *J. Bone Jt Surg.*, 64-A: 871–879, 1982.
35. MULLER, M. E., NAZARIAN, S., KOCH, P., SCHATZKER, J.: The Comprehensive Classification of Fractures of Long Bones. Springer-Verlag; 1990.
36. NEER, C. S., GRANTHAM, S. A., SHELTON, M. L.: Supracondylar fracture of the adult femur. A study of one hundred and ten cases. *J. Bone Jt Surg.*, 49-A: 591–613, 1967.
37. NORK, S. E., SEGINA, D. N., AFLATOON, K., BAREI, D. P., HENLEY, M. B., HOLT, S., et al.: The association between supracondylar-intercondylar distal femoral fractures and coronal plane fractures. *J. Bone Jt Surg.*, 87-A: 564–569, 2005.
38. OH, J. K., HWANG, J. H., LEE, S. J., KIM, J. I.: Dynamization of locked plating on distal femur fracture. *Arch. Orthop. Trauma Surg.*, Epub 2011 Jan 8, 131: 535–539, 2011.
39. OLERUD, S.: Operative treatment of supracondylar-condylar fractures of the femur. Technique and results in fifteen cases. *J. Bone Jt Surg.*, 54-A: 1015–1032, 1972.
40. PAPADOPOULOS, E. C., PARVIZI, J., LAI, C. H., LEWALLEN, D. G.: Total knee arthroplasty following prior distal femoral fracture. *Knee*, 9: 267–274, 2002.
41. SANDERS, R., REGAZZONI, P., RUEDI, T. P.: Treatment of supracondylar-intracondylar fractures of the femur using the dynamic condylar screw. *J. Orthop. Trauma*, 3: 214–222, 1989.
42. SCHANDELMAIER, P., PARTENHEIMER, A., KOENEMANN, B., GRÜN, O. A., KRETTEK, C.: Distal femoral fractures and LISS stabilization. *Injury*, 32 (Suppl. 3): SC55–63, 2001.
43. SCHATZKER, J., HOME, G., WADDELL, J.: The Toronto experience with the supracondylar fracture of the femur, 1966–72. *Injury*, 6: 113–128, 1974.
44. SCHÜTZ, M., MÜLLER, M., KRETTEK, C., HÖNTZSCH, D., REGAZZONI, P., GANZ, R., et al.: Minimally invasive fracture stabilization of distal femoral fractures with the LISS: a prospective multicenter study. Results of a clinical study with special emphasis on difficult cases. *Injury*, 32 (Suppl. 3): SC48–54, 2001.
45. SEINSHEIMER, F.: Fractures of the distal femur. *Clin. Orthop. Relat. Res.*, 153:169–179, 1980.
46. SHAHCHERAGHI, G. H., DOROODCHI, H. R.: Supracondylar fracture of the femur: closed or open reduction? *J. Trauma*, 34: 499–502, 1993.
47. STEWART, M. J., SISK, T. D., WALLACE, S. L.: Fractures of the distal third of the femur: A comparison of methods of treatment. *J. Bone Jt Surg.*, 48-A: 784–807, 1966.
48. STOVER, M.: Distal femoral fractures: current treatment, results and problems. *Injury*, 32 (Suppl. 3): SC3–13, 2001.
49. VALLIER, H. A., HENNESSEY, T. A., SONTICH, J. K., PATTERSON, B. M.: Failure of LCP condylar plate fixation in the distal part of the femur. A report of six cases. *J. Bone Jt Surg.*, 88-A: 846–853, 2006.
50. WEIGHT, M., COLLINGE, C.: Early results of the less invasive stabilization system for mechanically unstable fractures of the distal femur (AO/OTA types A2, A3, C2, and C3). *J. Orthop. Trauma*, 18: 503–508, 2004.
51. WONG, M.-K., LEUNG, F., CHOW, S. P.: Treatment of distal femoral fractures in the elderly using a less-invasive plating technique. *Int. Orthop.*, 29: 117–120, 2005.
52. WU, C. C., SHIH, C. H.: Treatment of femoral supracondylar unstable comminuted fractures. Comparisons between plating and Grosse-Kempf interlocking nailing techniques. *Arch. Orthop. Trauma Surg.*, 111: 232–236, 1992.
53. ZLOWODZKI, M., BHANDARI, M., MAREK, D. J., COLE, P. A., KREGOR, P. J.: Operative treatment of acute distal femur fractures: systematic review of 2 comparative studies and 45 case series (1989 to 2005). *J. Orthop. Trauma*, 20: 366–371, 2006.
54. ZLOWODZKI, M., WILLIAMSON, S., COLE, P. A., ZARDIACKAS, L. D., KREGOR, P. J.: Biomechanical evaluation of the less invasive stabilization system, angled blade plate, and retrograde intramedullary nail for the internal fixation of distal femur fractures. *J. Orthop. Trauma*, 18: 494–502, 2004.
55. ZLOWODZKI, M., WILLIAMSON, S., ZARDIACKAS, L. D., KREGOR, P. J.: Biomechanical evaluation of the less invasive stabilization system and the 95-degree angled blade plate for the internal fixation of distal femur Fractures in human cadaveric bones with high bone mineral density. *J. Trauma*, 60: 836–840, 2006.

**Corresponding author:**

Professor Dr. med. Reto Babst, MD  
Department of Trauma Surgery  
Cantonal Hospital Lucerne  
6000 Lucerne 16, Switzerland  
E-mail: reto.babst@luks.ch