The use of a low-profile Ilizarov external fixator in the treatment of complex fractures and non-unions of the distal femur

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The aim of this study was to assess the effectiveness of a modified (low-profile) Ilizarov fixation in the treatment of complex fractures of the distal femur such asseptic or aseptic non-unions following previous surgeries, osteoporotic fractures, and high-grade open fractures.

Ten male patients with a mean age of 50 years (range, 22-72 years) were treated with a modified Ilizarov fixator. The system was composed of tensioned olive wires attached to four 5/8 rings (two proximal and two distal to the fracture line) connected to each other with three rods. The fixator was not extended to the proximal femur nor across the knee to the tibia, and no Schanz screws were used. The main outcomes evaluated were union, time in fixator and IOWA knee score.

Time in the fixator averaged 158 days (range, 125-180). Mean follow-up was 74 months (range, 24-108 months). All fractures united without major complications. One case healed with a 3° varus angulation at the fracture site. The mean IOWA score was 83.8 (range, 70-98). Although superficial pin-tract infection was observed at 10 pin sites, no patient developed deep infection requiring premature pin removal. There was breakage of one wire, which was replaced under anaesthesia, and one patient presented a patella fracture after a fall, which healed after tension-band wire fixation.

Considering the high union and low complication rates, we suggest the use of a low-profile Ilizarov fixator in the management of certain distal femoral fractures and non-unions that may be difficult to manage using other means of fixation.

INTRODUCTION

Several treatment options are available for fractures of the distal femur which require internal fixation, using various plates (condylar, dynamic condylar, locked) or nails (ante-retrograde) (*10-13,16,18,23,26,37,38*). Stability of the distal meta-physo-epiphyseal fixation determines the success of internal fixation, and depends on the amount and quality of the bone stock. Because the distal femur has an abundant blood supply and good intrinsic

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healing capacity, distal femoral non-unions are rare. However, when they do occur, union is difficult to obtain (22). Fractures of the distal femur in patients with poor bone stock are challenging because of inadequate fixation strength and high failure rates (4,15,17,33,36,39). Up to 80% of the patients with distal femoral fractures are over 50 years of age, and osteoporosis is the most common reason for poor bone quality (18,37). A short distal fragment, poor bone stock, proximity to the knee joint, and the pull of the gastrocnemius muscles are factors leading to non-unions in distal femoral fractures (22). High-energy open fractures seen with severe comminution and non-unions after failed internal fixation are other reasons for bone loss. Previous treatment options in this subgroup of patients include revision internal fixation with locked plates, revision nails, addition of bone cement to internal fixation, unilateral and Ilizarov-type external fixators and primary total knee arthroplasty (3,6,13,19,21-23,33,38-41,44,45). Internal fixation methods have the disadvantages of a lengthy period of limited weight bearing and high rates of hardware failure, both of which entail for the geriatric patient a serious risk of medical complications ; mortality rates of up to 22% have been reported (4,17,38,39,41). In revision cases, arthrodesis or even above-knee amputation may be considered as a salvage procedure (17,26).

External fixation is a reasonable alternative for these fractures since it provides adequate fixation and stabilization for early weight bearing. Additionally, the tensioned wires of the Ilizarov external fixator provide adequate stability even in osteoporotic bone. However, circular fixators at the femur are poorly tolerated and have other drawbacks which may adversely affect the outcome, such as pin-tract infection, bulk of the fixator, as well as soft-tissue binding and joint stiffness (13,24,32,34). The classical Ilizarov frame including three or four partially threaded half pins in the upper semicircular ring and two to four wires on distal circular rings, necessitates major changes in daily life, difficulties in moving freely, discomfort at night and serious sleep disturbances (46). Distal femoral circular rings or extension of the fixator across the knee interfere with knee flexion and sitting and lying comfort (5,9,24) : they interfere with the use of a standard bed and chairs and affect the patient's compliance.

We modified our treatment strategy to use a low-profile Ilizarov external fixator for the treatment of complex distal femoral fractures or non-unions with poor bone stock, in order to reduce the bulk of the fixator and to improve joint motion, patient mobility and comfort in daily activities such as sitting and lying. This study was designed to evaluate mid-term results using a semicircular Ilizarov external fixator in a subgroup of patients who would not have been treated easily with standard methods of fixation.

PATIENTS AND METHODS

Between January 1998 and December 2003, 10 patients presenting with a complex distal femoral fracture or non-union were considered for treatment with a low-profile semicircular external fixation. The inclusion criteria were distal femoral fractures with either (a) non-union of a previous internal fixation procedure, (b) advanced age (> 70 years) and osteoporosis and (c) high-grade open fractures with comminution and infection complicating internal fixation. The clinical and surgical records, radiological findings and functional data available for all 10 patients were reviewed.

The Ilizarov instrumentation set has various sizes of arches including 5/8 half-rings. The system was composed of a distal segment with two 5/8 rings connected with each other with three rods and a proximal segment with two 5/8 rings also connected with each other with three rods (figs 1&2). We have used only 5/8 rings. The distance between the two rings in the proximal segment was a minimum of 4 cm ; however, the distance between the two rings in the distal segment was dependent on the fracture configuration, and ranged between 2 and 4 cm (3 cm on average). Prior to fracture manipulation, each bone segment was transfixed by four 1.8 mm olive wires. The first two wires were directed from posteromedial to anterolateral and the next two wires from posterolateral to anteromedial. Once all pins were placed and secured to individual arches or rings, a closed reduction of the fracture was performed under fluoroscopic guidance. In non-unions and open fractures, open reduction was performed after removal of the hardware or debridement. When an acceptable reduction was achieved, three evenly spaced threaded rods were inserted between the two segments, which should be essentially parallel to each other. Olive wires were used to prevent movement of the
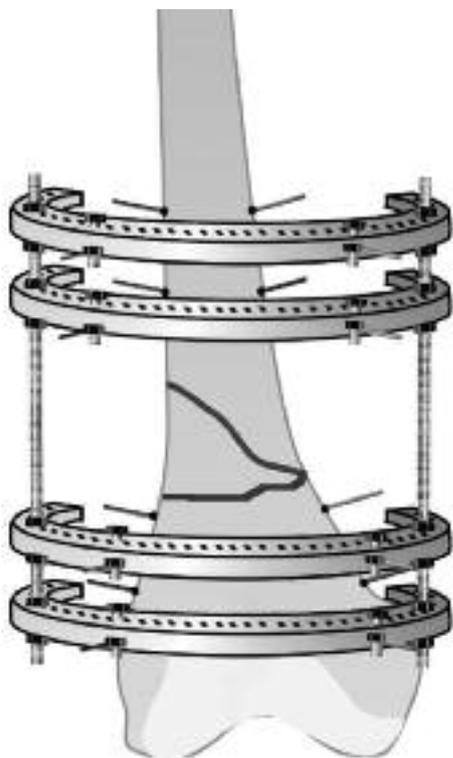
Fig. 1. — Wire and ring configurations in the low-profile Ilizarov fixation.

Fig. 2 a&b. — Anterior and posterior photographs of the supracondylar femoral fracture in patient #. 8 with a previous history of chronic osteomyelitis and septic arthritis sequelae. A healed fistula tract can be seen (arrow).

construct in the mediolateral plane. No extension across the knee to the tibia was used. The system was not extended to the proximal femur and no Schanz screws were used. No bone graft or synthetic bone substitute was used in any of the patients. No resection was used in non-union cases ; however, compression at the non-union site was performed manually before final locking of the construct. No fracture table was used. After fixation of the whole system, the knee was flexed to the maximum possible degree of flexion (full flexion in fresh fractures and maximum amount of flexion depending on the preoperative range of motion [ROM] in the non-union cases) to release the iliotibial band. All patients received parenteral antibiotics for two days. In septic non-unions, appropriate antibiotherapy was continued for six weeks. Patients were allowed to shower two weeks after surgery after removal of the sutures. The patients were advised to perform pin site care by daily showering and cleaning the crusts using sterile gauze impregnated with 10% polyvinylpyrrolidone iodine. Pin sites were left open (without any sterile covering) afterwards.
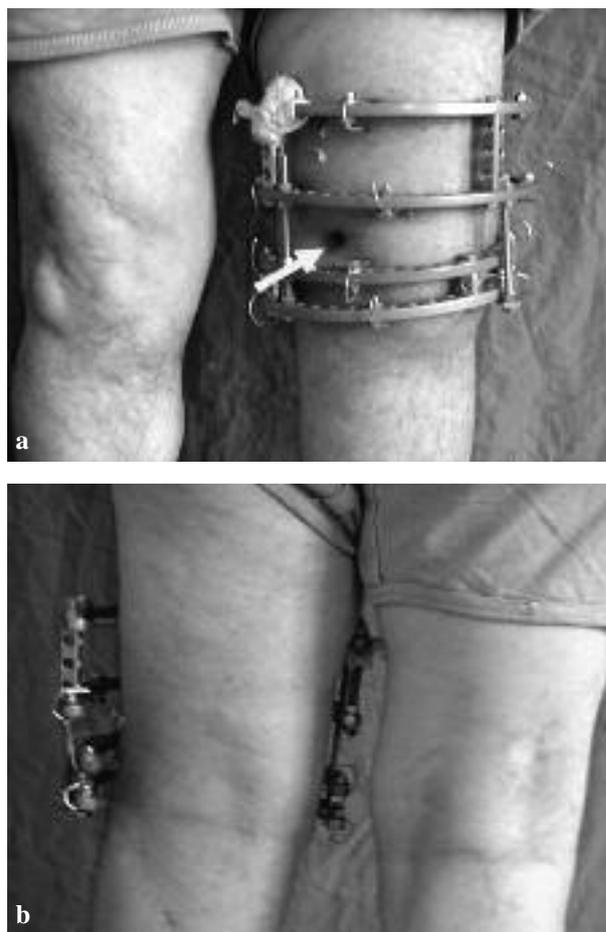
Postoperative treatment was started on the second postoperative day and included full weight bearing as tolerated, muscle strengthening and ROM exercises . Quadriceps isometric exercises were started immediately after the operation. No guided compression or distraction was used in any of the cases. In cases with varus or valgus angulation, minor adjustments were made as appropriate. However, since the proximal and distal segments of the fixator were close to the fracture or non-union site, no major adjustments could be done.

All patients were followed monthly for routine clinical and radiological examination until the external fixator was removed, and every three months in the following year. Postoperative radiographs were evaluat-

ed for residual malalignment and evidence of union. Radiological union was defined as the absence of a radiolucent line at the site of the fracture at a minimum of three cortices on standard AP and lateral radiographs (44). In addition to radiological measures, the ability to walk painlessly on a fully dynamized fixator without any walking aids was used as a clinical indicator for fixator removal.

The results were assessed using the functional and radiological scoring system described by Paley and Maar and the IOWA knee score (25,31). Complications that occurred during surgery, distraction-compression or thereafter were evaluated according to the Paley working classification as a 'problem', 'obstacle' or 'true complication' (29).

RESULTS

All patients were male with a mean age of 50 years (range, 22 to 72). The mechanisms of injury were motor vehicle accidents (4), gunshot injury (3), simple fall (2) and fall from a height (1). Distal femoral fractures were classified as A2 (3), A3 (4) and C2 (3) according to the AO/ASIF system (27). There were four non-unions with previous internal fixation. The reasons for poor bone quality

were open fracture (3), non-union (4), osteoporosis (1), osteoporosis and open fracture (1) and osteomyelitis (1). The open fractures were classified according to Gustilo and Anderson as type-II (n : 1) and type-IIIA (n : 3) fractures. In four patients with non-union, initial treatment of the fracture consisted of open reduction and internal fixation (ORIF) (n : 3) and monolateral external fixator (n : 1). All were atrophic non-unions (fig 3a&b). The time interval from the original injury to application of the Ilizarov fixator was 10 to 24 months in patients with previous surgeries. Preoperative ROMs are given in table I.

Operative time for the reconstruction procedure averaged 70 minutes (range, 50-140 minutes), and no intra-operative complications occurred. The mean follow-up period was 74 months (range, 24-108 months). The mean time in frame was 158 days (range, 125-180 days). Clinical and radiological unions were achieved in all 10 patients in an average of 5.2 months (range, 4.2-7.8 months) after one operation without additional procedures (fig 3c-f). At the time of the latest follow-up, all 10 patients were able to bear weight fully on the affected leg without any walking aid or brace. They had no pain

Table I. — Patient demographics, and fracture classifications

Case	Gender	Age	Mechanism of injury	Associated injuries / treatments	Poor bone stock	AO classification (27)
1	M	25	Traffic Accident	–	IIIA Open fracture	C2
2	M	70	Traffic Accident	–	Osteoporosis	A2
3	M	58	Gunshot injury	Ipsilateral Talar Fract.+ Contralateral bimalleolar fx / ORIF for both	Nonunion	A3
4	M	23	Gunshot injury	–	IIIA Open fracture	C2
5	M	50	Traffic Accident	Tibia fx / external fixator	Nonunion	A3
6	M	22	Simple fall		Osteomyelitis sequellae	A2
7	M	72	Simple fall	Hemiplegia + subarachnoid bleeding	II Open fracture Osteoporosis	C2
8	M	66	Fall from a height	Infected nonunion + stiff knee	Nonunion	A3
9	M	61	Traffic Accident	–	Nonunion	A2
10	M	54	Gunshot injury		IIIA Open fracture	A3

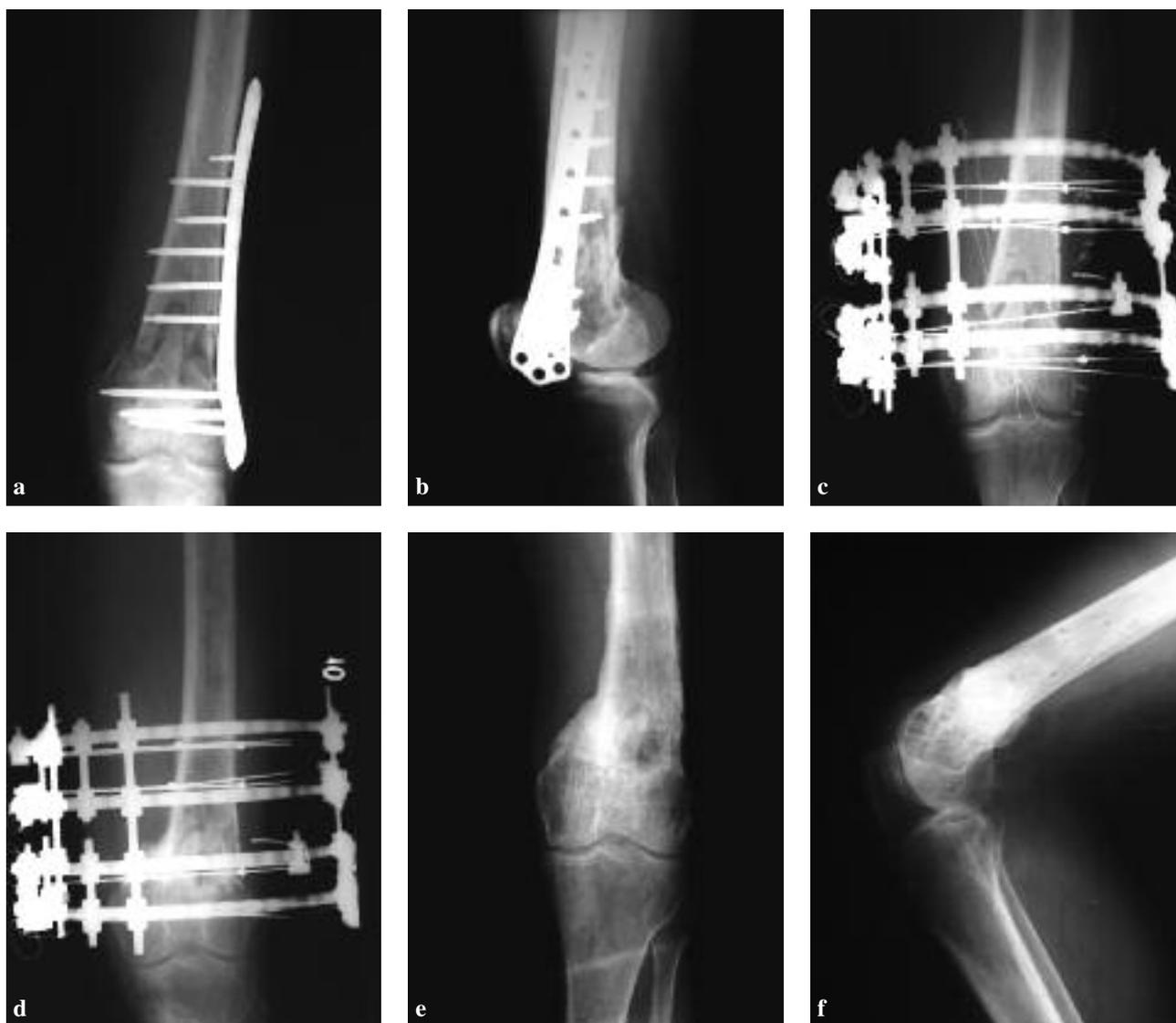ORIF : Open reduction/internal fixation.

Fig. 3 (a-f). — These radiographs show the treatment of a distal femoral non-union secondary to fixation with a locking plate (Patient # 3). (a,b) Anteroposterior and lateral radiographs show non-union of the femur. (c) Early postoperative radiograph demonstrating the frame configuration and a good reduction of the non-union site. No major debridement was performed. (d) This radiograph shows healing at the non-union site 3 months after operation. (e,f) Anteroposterior and lateral radiographs show completed bone union 18 months after operation. Malunion with a 3° varus angulation at the fracture site.

or only mild pain in activities of daily living. Only two patients had obvious limp, due to a hemiparesis in one and a talar fracture in the other.

There was one case with a malunion, with 3° varus angulation at the fracture site. There was no refracture, vascular injury, or need for knee manipulation and no cases of pin-site infections requiring pin removal or exchange. According to

Paley and Maar's grading system, two patients had excellent, four good, and four fair results. The mean IOWA score was 83.8 (range, 70-98). Superficial pin-tract infections occurred at 10 pin sites (6.2%) and were treated with local wound care. These were considered as an "obstacle". There were no deep infections necessitating pin removal or surgical debridement.

Table II. — Previous surgeries, complications and results of the last control are listed

Case	Previous surgeries	Frame period (days)	Follow-up (months)	Complications	Range of motion (degrees)	Shortening (cm)	Paley score *(31)*	IOWA score *(25)*
1	–	150	99	–	10 to 110	–	Good	85
2	–	155	88	–	0 to 140	–	Excellent	98
3	LISS (pre-op ROM, 0-70°)	180	18	–	0 to 90	1	Fair	77
4	–	165	95	–	10 to 120	–	Good	97
5	Unilateral external fixator (pre-op ROM, 0-90°)	150	85	–	10 to 100	3	Good	85
6	Debridement Sequestrectomy	140	94	–	10 to 140	2	Excellent	95
7	–	180	61	–	10 to 110	–	Fair	70
8	2 times ORIF (pre-op ROM, 0-40°)	150	48	Wire breakage	10 to 40	2	Fair	71
9	ORIF (pre-op ROM, 0-40°)	180	108	–	10 to 50	–	Fair	75
10	–	125	43	Patella fracture (4 months post-op)	10 to 100	–	Good	85

ORIF : Open reduction/internal fixation ; LISS : Less-invasive stabilisation system.

Two postoperative mechanical complications occurred. One wire breakage in the proximal ring of the distal segment was observed in the 3ʳᵈ postoperative month ; the wire was replaced under anaesthesia, and another patient broke his patella after a fall 125 days after initial treatment. Since he had no pain on full weight bearing, the frame was removed under anaesthesia and the fracture site was controlled by fluoroscopy. No movement was observed and no additional fixation was used for the femoral fracture. The patellar fracture was treated by ORIF with the tension wire technique. Early ROM exercises were initiated. No restriction of weight bearing or knee ROM was applied.

The mean ROM at the time of frame removal was 90° (range, 40°-130°), but at the end of the one-year follow-up, the minimum measured ROM was 80°. In four patients with non-union and one patient with osteomyelitis sequelae, there was limited ROM ; however, ROM was improved by a mean of 10° (5-20°) when compared with the preoperative status.

DISCUSSION

Distal femoral fractures account for approximately 4% of all femoral fractures (*18*). The most common method of treatment is internal fixation, and satisfactory results have been reported using several different techniques and fixation materials (*35,11,20,37*). Although internal fixation is used for primary and revision cases, secure bone implant fixation is vital for the success of these techniques and it has a high rate of failure, up to 25%, in osteoporotic, geriatric patients (*4*). In osteoporotic distal femoral fractures, in fractures with bone loss and also in open high-energy fractures with associated

contamination, additional devitalization of meta-physeal bone fragments from extensive surgical exposure and use of bulky internal fixation devices may result in septic or aseptic non-union (20,36). Improved fixation with bone cement or intramedullary fixation decreases non-union and reoperation rates to 10-18% (39). Poor bone quality associated with either osteoporosis, non-union or open fractures, as in our series, makes these fractures difficult to treat. All types have been reported as being similarly difficult to treat and diverging results have been reported with revision internal fixation using either nails or plates, and complications have included persistent non-union, malalignment and joint stiffness (19,26,44,45).

Early mobilization and ambulation are universal postoperative approaches to prevent complications including deep venous thrombosis (DVT), pneumonia, and decubitus ulcers, which result in mortality rates up to 20% in the geriatric population (4,7,17,33,39). For the elderly patient, primary arthroplasty has been suggested in order to increase the mobility and decrease time of confinement to bed or wheelchair (33). Vasarhelyi et al (43) stated that the reliability of partial weight bearing after surgery for fractures of the lower extremity is questionable, especially for elderly patients, indicating the need of fixation methods allowing full weight bearing in the early postoperative period in this sub-group of patients (16,19,45). In our series, all patients were allowed uncontrolled weight bearing as tolerated and all began to walk independently with walking aids in the immediate postoperative period. One patient (case no : 7) with a Type II open fracture after a fall secondary to a recent cerebrovascular event was able to walk with one crutch with full weight bearing on the fractured femur, which was on the plegic side.

Distal femoral non-unions were reported in the literature to be rare (range, 0-4%) and difficult to treat because of thin cortex, short distal fragment, poor soft tissue coverage and poor bone stock due to disuse atrophy and implant failure (10,12,39). There are several alternative techniques available for the treatment of distal femoral non-unions. Intramedullary nailing has the advantages of minimal soft tissue trauma and it provides a load-shar-

ing implant. However, its insufficiencies in deformity correction and in stable fixation at the distal fragment due to poor hold of the distal locking screws limit its use in non-unions with poor bone quality and restrict early weight bearing (16,19,45). In two series of femoral non-unions, intramedullary nailing was reported to fail in 30% of patients using antegrade and 50% using retrograde techniques (19,45). Recently, fixed angle locking screw-plate implants have been popularized because compression forces and friction of the plate on the bone surface are not necessary to gain stability of the bone-implant construct, which results in lower rates of screw pull-out in osteoporotic bones (8). However, locking plates have also had hardware failure rates up to 40% in non-unions and still require a lengthy period of limited weight bearing to achieve fracture union as with any other internal fixation method, which contradicts the principles of early ROM and weight bearing (33,39,42).

Open fractures secondary to traffic accidents and gunshot injuries are also problem fractures because of soft tissue stripping and comminution. Formal internal fixation with plating and bone grafting may end up in an infected non-union which would be more difficult to treat (26). Recent studies showed that minimally invasive plating in those fractures can result in acceptable outcomes ; however the need for bone grafting and deep infection is still a problem (40,42). The Ilizarov external fixation is a well established treatment for many complex musculoskeletal disorders, including open and comminuted fractures, non-unions and osteomyelitis (3,13,15,21,36). Tensioned small-diameter wires have been reported to provide sufficient stability, even in osteoporotic bone (3). The method has several advantages, including shorter operating time, limited blood loss, greater mechanical stability than with a monolateral external fixator, and early weight bearing, which is the most important advantage, potentially decreasing serious medical complications related with immobilization (1,3,5,33). However, the most commonly used hybrid fixation includes circular rings with tensioned wires combined with a semicircular ring in the upper femur fixed with Schanz screws. Ilizarov suggested that, in some cases, only one ring is required for each

bone segment considering the tension of soft tissues, which help to stabilize a frame (*14*). However, usually two levels of fixation or two rings are used per segment to obtain adequate frame stability (*2,30*). For the correction of deformities and stabilization of oblique fractures where considerable bending movements are involved, including the distal femur, a minimum of two double-ring blocks is required, one for each bone segment, as used in our study (*30*). The stability is also dependent on the configuration of the wires. Orbay *et al* stated that the bending rigidity of a ring with a 90° wire-convergence angle can be achieved by any two-wire configuration, by placing a third wire at least 4 cm from the primary ring (*28*). We placed the second proximal ring at a minimum distance of 4 cm from the first proximal ring.

The use of the Ilizarov circular fixator is psychologically stressful because of its long duration and many complications, such as pin-tract infection and adjacent joint stiffness. The Ilizarov configuration with proximal half pins and circular frames entails difficulties in patient compliance because of the difficulties in performing daily activities such as lying, sitting and sleeping. Yildiz *et al* reported a sleeping problem rate of 32% in their series of 40 adults (*46*). Moreover, the need for extension of the fixator across the knee in distal fractures makes patient usage more difficult (*5,9,24*). Realizing the potential relationship between the bulk of the fixator and daily life, we modified the Ilizarov frame in order to improve daily activities such as lying, sitting on a chair and sleeping. Our low-profile fixator with a combination of semicircular rings improved the sitting and lying comfort of the patient.

Although the quality of bone is not as important as in other techniques of osteosynthesis, tensioned K-wires are criticized for impaling the joint capsule and impeding motion. Pin-tract infection is a risk when using periarticular tensioned wire external fixation (*13,24*). In this series, there were only a few obstacles in the form of superficial pin-tract infections, which recovered without intervention. One patient who presented a patellar fracture recovered after tension wire fixation, and one broken wire was replaced without additional problems. There were no serious complications necessitating an addition-

al operation. The wires and pins used in the femur pass through the quadriceps muscle, thereby acting as a checkrein to the movement of the knee while the fixator is in place. We thus carried out the operation in a position of moderate knee flexion and achieved a good ROM and satisfactory functional results as indicated by IOWA and Paley scores in patients without previous surgery. In patients with non-union, ROM was limited due to long immobilization periods ; however, there was no additional loss in ROM or functional scores, and even a slight increase was observed. Despite the fact that our series was relatively small, it is noteworthy that early weight bearing could be applied with the initial stabilization, and additionally the patients were more comfortable during daily activities of living due to the ease supplied by the 5/8 rings.

We conclude that the use of a low-profile Ilizarov system for fixation of fractures of the distal femur with poor bone quality appeared in this series to be safe and to provide adequate stabilization for early weight bearing, with a low incidence of obstacles such as pin-tract infections. In our series, the use of the Ilizarov method achieved limb salvage with no need for arthrodesis or amputation. Based on this experience, we consider that the use of 5/8 ring Ilizarov fixation in the treatment of distal femoral fractures with poor bone quality is a well-tolerated and effective method that can provide satisfactory and reproducible results.

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