Modified Ilizarov technique for infected nonunion of the femur: the principle of distraction-compression osteogenesis

A Krishnan, C Pamecha, JJ Patwa
Department of Orthopaedics, Sheth KM School of PG Medicine and Research, Smt NHL Municipal Medical College, Ahmedabad, India

ABSTRACT

Purpose. To evaluate the treatment outcome of the modified Ilizarov technique in infected nonunion of the femur.

Methods. Between 1989 and 2002, records of 20 patients with infected nonunion of the femur treated with the modified Ilizarov technique were retrospectively reviewed. The modified Ilizarov frame was fixed after necrectomy of the dead infected bone and tissues. A proximal or distal corticotomy was performed following biological principles. For regeneration of gap, segmental transport was performed in 11 patients with a gap of more than 5 cm; acute docking followed by lengthening at the corticotomy site was performed in 9 patients with a gap of smaller than 5 cm. Mobilisation was started early with active participation of the physical therapist and the patients. Bone and functional results were measured and complications were categorised according to the Association for the Study and Application of the Method of Ilizarov guidelines.

Results. The mean follow-up period was 62.8 months. Bony union and eradication of the infection was achieved in all patients except one who underwent amputation due to uncontrolled infection. Bone results were excellent in 13 patients, good in 4, fair in one, poor in one, and treatment failure (amputation) in one. Functional results were excellent in 3 patients, good in 9, fair in 3, poor in 4, and failure in one. A total of 71 complications occurred: 35 problems, 6 obstacles, and 30 true complications. The mean healing index was 38.3 day/cm (standard deviation, 1.6 day/cm).

Conclusion. The Ilizarov technique is a good salvage operation for infected nonunion of the femur. Limb salvage is preferable to prosthesis if the limb is viable, adequately innervated and the patient is mentally and financially committed to save the limb.

Key words: femoral fractures; fixators, external; fractures, nonunited; Ilizarov technique; infection; osteogenesis, distraction

INTRODUCTION

Conventional methods for treating infected nonunion of the tibia includes external fixation, drainage, sequestrectomies, and massive cancellous bone grafting. They are often unsuccessful due to limita-
tions including: quantity of graft available, donor-site morbidity, poor vascularity, persistence of infection, and extensive bone defects and deformity. The incidence of refracture is high. External fixation with debridement and massive bone grafting for infected nonunion of the femur has also been reported. Microvascular composite tissue transfer has given promising results in the tibia and femur. Nonetheless, it has limitations in regaining length and correcting deformity and requires expertise. Electrical stimulation has been used in osteogenesis with or without bone grafting in delayed union or non-union. The results are uniformly poor in patients with coexisting infection and fracture instability. All these modes of treatment are inadequate for achieving limb length equality and deformity correction.

In 1951, Ilizarov began to use distraction osteogenesis to treat acute fractures. Over the years, the methods and devices have evolved and its indications have been extended to treat fractures and associated complications: nonunion, chronic osteomyelitis, shortened extremity, joint contracture, and deformity. The Ilizarov technique for infected nonunion consists of removal of infected tissues and bone, stabilisation with ring fixators, and regeneration of intercalary bone defect by distraction osteogenesis, compression at the nonunion site, and correction of the deformity. The regenerated bone restores length and eliminates infection. Disuse osteoporosis and soft-tissue atrophy is minimised due to early functional loading of the limb. Therefore, the use of Ilizarov technique for infected nonunion of the tibia is increasingly popular. Nonetheless, reports describing large series of patients with infected nonunion of the femur treated with the Ilizarov technique are scarce. We retrospectively reviewed the results of 20 patients with complicated infected nonunion of the femur treated by the Ilizarov technique with Catagni-Cattaneo modification. The treatment goal was bony union and eradication of infection. Potential complications are the same as with treatments using fixators or a limb lengthening apparatus, though the incidence and severity of these complications have decreased.

**MATERIALS AND METHODS**

From 1989 to 2002, records of 20 patients (17 men and 3 women) aged 18 to 65 years (mean, 38.4 years) with infected nonunion of the femur treated with the modified Ilizarov technique were retrospectively reviewed. The causes of injury were traffic accident in 18 patients, a fall from height in one, and gunshot in one. 13 patients had open and 7 had closed fractures. Ten patients fractured the lower third of the femoral shaft, 8 the middle third, and 2 the proximal third. 11 patients had additional injuries (limb fracture, head, chest, or abdominal injury). In 12 patients the fracture was comminuted and multifragmentary. All 20 patients had received prior conventional treatments. The mean period from fracture to Ilizarov treatment was 9.5 (standard deviation [SD], 6.3; range, 3–24) months. The patients had undergone a mean of 4.4 (SD, 2; range, 1–9) operations before the Ilizarov treatment was considered. Nine patients had undergone fixation previously (plate osteosynthesis=5, interlocking nail=1, external fixators of the AO tubular type=3). Three patients had been treated by traditional bonesetter bandages, 8 by skeletal traction, 6 of whom had open fractures. At presentation, 18 patients had nonunion with active infection and discharging sinuses; 2 had no signs of active infections, though quiescent sinuses were present. Hip and knee functions were severely affected; 10 patients had knee flexion of <30°, 2 up to 50°, and the remaining 8 had completely stiff knees.

Patients were thoroughly evaluated and psychologically assessed. The arduous treatment programme was explained. Radiographs were taken in at least 2 planes, and sinograms performed in patients with sinuses (to enable better identification and resection of the septic focus). A modified Ilizarov frame was preconstructed using a proximally lateral mounting apparatus with arches together with single and multiple pin fixation bolts. Up to 2 rings were used for the distal fragment and one full ring for the planned intercalated segment. The proximal construct was connected to the middle and distal construct using oblique supports, as well as threaded and telescopic rods.

Patients were operated under spinal anaesthesia and the involved leg was placed in traction through straps and abducted adequately to permit access to the thigh medially and laterally. Preoperatively methylene blue was injected into sinuses for complete excision of the infected and dead tissues. Existing implants were removed and the bone was resected transversely to remove all circumferential defects. The medullary canal was opened on both sides. Punctate cortical bleeding (paprika sign) was used to determine the completeness of bone debridement. The preconstructed sterilised Ilizarov frame was applied after necrectomy. Rings were fixed to the bone, distally first, then to the middle and proximal sections to maintain the mechanical axis of the femur by keeping the rings parallel to the tibial articular surface of the knee joint. Moreover, adjustment of
the proximal construct after fixation of the middle and distal rings is easier than the converse sequence. Full rings of the middle and distal constructs were reinforced with tensioned 1.8-mm olive wires through the rings; Schanz screws were applied for additional stability if required, especially in osteoporotic bone. To avoid damage to vital structures, olive wires were inserted according to the level of the femur and were directly guided by the goniometric atlas of the Association for the Study and Application of the Method of Ilizarov (ASAMI).12 The proximal construct was completed with 3 to 5 bicortical Schanz screws through pin fixation bolts. The Schanz screws were 4.5 mm in size and inserted after predrilling with a 3.2 mm drill bit. The screws were fixed through the fixation bolts in the arch in a multiplanar way within the safe corridor of the proximal femur from 30° to 150° laterally (Fig. 1). For bifocal osteosynthesis, the intercalated segment of bone was created by corticotomy in the proximal or distal part of the femur, according to the level of infected nonunion. A 1.5-cm lateral incision was used to obtain a biological corticotomy/compactotomy. The cortex was subperiosteally cut with a 5-mm straight osteotome (or 7-mm corticotome)—first laterally, then anteriorly and posteriorly. The corticotomy was completed medially by twisting the osteotome or by rotating the frame if necessary. Distal femoral corticotomy was performed in 7 patients and a proximal femoral corticotomy in 13. In 4 patients of severe infection, corticotomy was delayed for 2 weeks to avoid infection of the site. Intramedullary guide wire was used in 3 patients to aid the segmental transport and to prevent its deviation during distraction. All these patients required more bone to be regenerated (>8 cm). Intramedullary guide wires (ender nail or rush nail) were used prophylactically to prevent axial deviation, as in 2 of our cases with >8 cm transport. Severe axial deviation during distraction necessitated deformity correction with frame.

Acute docking was performed in 9 patients in whom the gap was <5 cm, which was followed by lengthening at the corticotomy site (Fig. 2). Segmental transport was carried out in the remaining 11 patients (Fig. 3). A latent period of 7 days was planned in 16 patients, in 4 of whom it was extended to 10 days (because of suspected inadvertent intramedullary damage during corticotomy). The rate and rhythm of distraction was 0.25 mm/6 hours (i.e. 1 mm/day).
If required, the anatomical and mechanical axes were corrected at the time of frame application or gradually during the distraction. Patients were put through a stringent postoperative protocol with a suitable diet, active/passive joint mobilisation and strengthening exercises, systemic antibiotics for 6 weeks according to culture/sensitivity results, and wound care (repeated debridement, irrigation, antibiotic instillation, and dressing changes) until healing was apparent. Apart from meticulous pin care, the apparatus was regularly checked for loosening and the wire was re-tensioned if required. A physical therapist actively participated in all stages of the treatment. Radiographs were taken in 2 planes at 3 weekly intervals until distraction-compression was complete, and subsequently at the time of frame removal, at 3 months, one year, and final follow-up. In case of inadequate regeneration, distraction was discontinued, reversed, and re-started at a reduced rate (0.25 mm/12 hours; Accordian manoeuvre) after a gap of 20 days. Patients were discharged after having learnt the method of distraction and so long as wound healing had started. They were followed up in the out-patient department weekly, or more often if wound care was required. Weight bearing with crutches/walker was started as soon as tolerated. After bifocal osteosynthesis was accomplished, the frame was left for a variable period of neutral fixation to complete corticisation of the regeneration prior to removal. The apparatus was dismantled based on radiological and clinical findings; after new bone had filled the gap from end to end and there was adequate remodelling of the circumferential cortex (>75% of the normal diameter). The distraction and compression stresses were removed by loosening the connecting rods. If the patient could tolerate weight bearing without pain and had a subjective feeling of solidity on the operated leg, after 3 weeks of dynamisation, the fixator was removed under the cover of dissociation anaesthesia. Patients were given a coxofemoral brace for 6 weeks and physiotherapy was encouraged.

Bone healing, the functional result, and complications were assessed according to ASAMI. Bone healing was evaluated based on union, infection, deformity, and limb length discrepancy as: excellent—union without infection, <7° deformity, and <2.5 cm limb length inequality; good—union with 2 of the above criteria; fair—union with one of the above criteria; poor—nonunion or refracture, and none of the above criteria fulfilled. Lengthening index (healing index or regeneration index) was calculated by dividing the frame-keeping period (days) by the length of the regenerated bone (cm). It was used to compare with the indexes in other studies.

The functional result was evaluated according to 5 adverse criteria: (1) observable limp, (2) stiffness of knee or hip (loss of >70° of knee flexion or >15° of knee extension), (3) loss of >50% of hip motion when compared with the normal contralateral side, (4) severe sympathetic dystrophy, pain that reduced activity or disturbed sleep, and (5) inactivity (unemployment or inability to return to daily activities). Provided the patient was active, the result was deemed excellent if the other 4 criteria were also absent, good if one or 2 of the other criteria were present, and fair if 3 or 4 of them prevailed. The result was deemed poor if the patient was inactive, regardless of the other criteria.

Complications that occurred during surgery, distraction-compression or thereafter were evaluated according to the Paley working classification:

1. A ‘problem’ is a difficulty arising during the distraction or fixation period and is fully resolved by the end of the treatment period by non-operative means.
2. An ‘obstacle’ is a difficulty arising during the distraction or fixation period and is fully resolved by the end of the treatment period by operative means.
3. A ‘true complication’ includes any local or
systemic intra-operative or peri-operative complication, a difficulty arising during the distraction or fixation period and remains unresolved at the end of the treatment period, and any early or late post-treatment complications. True complications are further divided into minor and major. Minor complications are nuisance problems that leave no significant residual impact on the patient other than being annoying or delaying treatment or rehabilitation. They do not prevent achievement of the treatment goal and can be resolved non-operatively. Major complications are defined as requiring surgery and are subdivided into those that do or do not interfere with achievement of the original treatment goals.

RESULTS

The bone results, functional results, and complications of these patients were evaluated. The mean follow-up period was 63 (SD, 25; range, 29–110) months. The mean frame-keeping period was 234 (SD, 124; range, 77–446) months. The mean length of regenerated bone was 6 (SD, 3; range, 2–10.5) cm. The mean limb length discrepancy was 0.5 (SD, 0.8; range, 0–2.5) cm. All patients were able to mobilise (weight-bearing) within a mean of 12 (SD, 7; range, 4–22) days.

Bony union was achieved in all but one patient, who had an uncontrolled infection and inadequate bone regeneration. He became impatient and unwilling to continue treatment, and ultimately had his limb amputated. Two patients developed delayed consolidation (poor regeneration), but responded favourably to the Accordian manoeuvre. One patient had refracture 2 weeks after frame removal and was treated with interlocking nails and cancellous bone grafting. No other patients had bone grafting.

Infection was controlled in all the patients, except the one whose limb was amputated. Only one patient had a 2.5-cm shortening after completion of treatment. Axial deformities of >7° were present in 5 patients. Three patients in whom an intramedullary guidewire was used developed no significant deformities. The mean lengthening index was 38.3 (SD, 1.6; range, 36–42) days/cm.

Four patients were unable to resume their previous jobs or level of daily activities and 14 had an observable limp. Major rigidity was present in 11 patients: 7 in the knee only and 4 in both the knee and hip. Severe dystrophy was present in 7 patients and 2 had occasional intractable night pains.

The bone results were excellent in 13 patients, good in 4, fair in one, poor in one and treatment failed (amputation) in one. The functional results were excellent in 3 patients, good in 9, fair in 3, poor in 4, and failed in one (Fig. 4).

A total of 71 complications occurred: 35 problems (2 delayed consolidation, 8 pin-site problems, one intractable pain, 5 severe oedema, 7 severe dystrophy, 9 loss of appetite/weight, and 3 depression); 6 obstacles (2 axial deviations, one premature consolidation, and 3 pin-site problems). 30 of these were designated to be true complications: 15 minor (6 joint stiffness, 7 axial deviations of <7°, and 2 occasional intractable pain) and 15 major (5 joint stiffness, 5 axial deviations of >7°, one shortening of regeneration, one non-union/amputation, one limb length inequality of >2 cm, one refracture, and one femoral bowing). Of the 15 major complications, 3 interfered with the achievement of our original goals: one patient with uncontrolled infection and nonunion had an amputation; one with refracture was treated with interlocking nails and bone grafting; and one had shortening of 2.5 cm and femoral bowing of 20°.

One patient with premature consolidation had a recorticotomy. Limb length inequality of >2 cm and femoral bowing of 20° occurred in one patient, in the plane of knee movement. Axial deformities developed in 14 patients of whom 2 had corrective apparatus adjustment for correction; 7 had bony union with <7° of axial deviation and 5 with >7° of axial deviation. Joint stiffness of varying degrees was present in all patients, but considerable functional loss was present in 11 (5 were manipulated under anaesthesia with little improvement). No patients were subjected to synoviolysis of the joint. Pin-site problems occurred in 11 patients: 8 responded well to local care and antibiotics and 3 required replacement of the wire.

Figure 4 Bone and functional results of 20 patients with infected nonunion of the femur treated with modified Ilizarov technique.

![Figure 4](image-url)
to maintain stability. Initially, variable oedema was present in all patients; it persisted during distraction in only 5 and disappeared before removal of frame. Dystrophy was evident in 7 patients but gradually improved. Pain was the most frequent complication (greatest during the first 4 to 6 weeks), for which paracetamol and/or tramadol were prescribed. Only 3 patients developed on and off intractable night pain that resolved around or after frame removal. Transient loss of appetite and weight occurred in 9 patients. Almost all patients were depressed before treatment started. After psychotherapy and medications were given, only 3 remained depressed during the entire first 6-week period; but all recovered after being able to stand and walk with the frame. None developed neurovascular complications.

**DISCUSSION**

The results of conventional treatment of infected nonunion of the femur are poor, due to high velocity primary trauma, multiple surgeries, late presentation, bone and soft tissue infection, nonunion, bone loss, osteoporosis, dystrophy, poor vascularity, associated deformities, and shortening. The Ilizarov technique is a salvage procedure for these difficulties. According to Ilizarov, gradual traction on living tissues creates stress that stimulates and maintains regeneration and active growth of tissues (bone, muscle, fascia, tendon, nerve, vessels, skin and its appendages). This principle is called "the law of tension stress." 20

The primary objective of the Ilizarov technique was to eliminate infection by increasing vascularity of the osteomyelitic centre through biological stimulation of a corticotomy (osteomyelitis burns in the fire of regeneration), but infection was not always cured. Therefore, thorough debridement before distraction osteogenesis is recommended. Distraction osteogenesis involves mechanical induction of new bone formation between bony surfaces that are gradually pulled apart. After corticotomy, bone transport entails movements of living bone segments to fill an intercalary bone defect. The trailing end generates bone by intramembranous ossification and the leading end fuses with the target bone surface. 12

The quality and quantity of the osteogenesis during distraction depends on the rigidity of bone fragment fixation, the degree of damage at the time of corticotomy, and the rate and the rhythm of distraction. 20 The biological response of the tissues to distraction is intrinsic and thus general body anabolism should always be positively maintained. 12

**my and necrectomy, an unintentional gap is created. The presence of a gap and an infection rules out the use of internal fixation, leaving only external fixation. The use of external fixation to treat infected nonunion of the femur has been previously reported. 3,5**

The universal-type external fixation requires repeated bone grafting to fill the gap. It is a cantilever fixation and not mechanically strong enough to allow mobilisation. Pin-track problems with larger pins as well as disuse osteoporosis and refracture are common. Moreover, it has a limited capacity to correct deformity and shortening.

The Ilizarov technique can overcome all these difficulties. Mechanically, the Ilizarov frame construct is very resistant to torsion and bending but allows axial compression during physiological loading. 12 It is an established method for treatment of infected nonunion of tibia, 13-15 nonetheless reports on large series of patients with infected nonunion of the femur treated by the Ilizarov technique are scarce. 8,16,17

Ilizarov used tensioned thin wires that occupy less space and thus confer lesser pin-track problems. But placement of wires in proximal segments of the femur is difficult, less well tolerated, and associated with frequent complications. ASAMI 12 therefore modified the frame and obtained better overall results by using a proximal half pin apparatus instead of a circular frame. We used a similarly modified frame with Schanz screws through the arch for the proximal femur. The transfixation tensioned olive wires for intermediate and distal rings are placed according to the guidelines of the goniometric atlas on the level of full rings along the femur. The Schanz screws through the proximal arch are inserted in the trochanteric and subtrochanteric region, following the safe corridors of the proximal femur described by ASAMI. 12 For all practical purpose, this entails avoiding the anteromedial and posteromedial region of the proximal femur for pin insertion and starting from the lateral aspect of the trochanter and subtrochanteric region. The stability of an assembly is proportional to the number of rings and the diameter, number, tension, degree of crossing, and location of the wires along the longitudinal axis of the bone. Half pin systems of uniplanar types are prone to cantilever loading, which introduces angular instability to the osteogenic site. Thus when using a half pin assembly in the proximal femur, the arrangement has to be multiplanar. Though the biomechanics may not be as strong as that of original Ilizarov apparatus, it serves its purpose well, being better tolerated and producing fewer complications, with greater ease of application and shorter operation time. 12,16 Being a deviation from the original Ilizarov concept of transfixing wires for the proximal femur, it
Cancellous bone grafting or refreshing of bone ends may be required at the site of docking.\textsuperscript{16,18,19} Nonetheless, bone grafting or refreshing was not required in our patients except in one with a refraction. Cancellous bone grafting and refreshing may reduce the frame-keeping period marginally and thus enhance healing.

Infection was eliminated and union was achieved in all patients except one. Refracture occurred in one patient, possibly due to premature removal of the frame. One patient developed femoral bowing of 20° and shortening of 2.5 cm. These 3 true major complications interfered with the achievement of our treatment goals. Shortening of bone regeneration after fixator removal can occur, if the regenerated bone has not corticalised adequately. One patient lost 2.5 cm of regenerated length with bowing. This complication may be avoided by a suitable radiological analysis and a guarded approach on the quality of bone regeneration.

A total of 71 complications occurred with a mean of 3.6 complications per patient. Complications are intrinsic to the Ilizarov technique but their frequency and severity decrease with experience. 85% and 60% of patients had good-to-excellent bone and functional results, respectively. The bone result was always better than the functional result, which is in keeping with other reports.\textsuperscript{8,16,18,19} Most patients present late, having had multiple previous surgeries with major damage to vessels, nerves, muscles, joints, and bone, and already having developed a variable amount of joint stiffness.

Bone transport over an intramedullary nail gives additional stability and reduces the period of external fixation and its complications. Nonetheless, it compromises the endosteal circulation and cannot be inserted in the presence of active infection; it also predisposes to necrosis of the moving segment and recurrence of infection.\textsuperscript{21,22}

Vascularised fibular grafting requires careful monitoring of the circulation and early intervention to avoid vascular failure. To improve results, internal bone transport requires repeated debridements, bone grafting at the docking site for early union, and avoidance of stress fractures.\textsuperscript{8}

The duration of external fixation and any associated complications can be substantially reduced with the technique of multiple segment lengthening, automatic high frequency lengthening, and extemporary compression at the end of traction.\textsuperscript{24}

**CONCLUSION**

Modified Ilizarov technique is a good salvage
operation for infected nonunion of the femur. The bone results are usually superior to the functional results. Functional results can be improved by the early use of the Ilizarov technique. Limb salvage is always preferable to a prosthesis, so long as the limb is viable, adequately innervated and the patient is committed to the financial and psychological demands of the procedure.

REFERENCES