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ORIGINAL STUDY

Ilizarov treatment for aseptic delayed union or non-union after reamed intramedullary nailing of the femur

Johan LAMMENS, Johan VANLAUWE

From Universitair Ziekenhuis Pellenberg, KU Leuven, Belgium

The authors reviewed eight patients treated with an Ilizarov frame for a non-infected delayed union or non-union after reamed intramedullary nailing of the femoral diaphysis. The hardware was completely removed in all cases but two, in which the distal fragment of a broken nail was left *in situ*. In five cases without shortening, progressive compression was applied. In the other three patients a simultaneous lengthening was performed using an additional percutaneous osteotomy. All patients achieved a good consolidation, with an average time to healing of 32 weeks and restoration of length and alignment if necessary. Bone grafting was never required, illustrating the sufficient biological potential for repair in non-infected femoral non-union.

Keywords : femur non-union ; reamed intramedullary nailing ; Ilizarov fixator.

INTRODUCTION

Non-union is an uncommon problem in femoral shaft fractures or osteotomies. Its incidence after reamed intramedullary nailing is reportedly lower than two percent (*3*). Femoral fractures usually heal uneventfully thanks to the large soft tissue envelope covering the femur and the well vascularised healing environment. The standard use of locked nailing provides good mechanical stability and allows quick rehabilitation, limited morbidity and solid consolidation (*14,20*). Compound fractures that are primarily treated with an external fixator or an unreamed nail usually heal well after revision to a reamed nail. Even in the case a non-union develops, exchange nailing has a success rate of more than 75% (*1,6,7,19*). Nevertheless, among a group of sixty patients sent to the authors' institution between 1998 and 2006 for different femoral healing problems – such as complex compound fractures or bone defects – 8 patients treated with reamed intramedullary nailing, either primarily or as a re-nailing, developed a non-union. All these patients were treated according to Ilizarov's method of compression or combined compression and distraction after removal of the hardware. In contrast to other methods such as bone grafting with repeated osteosynthesis, it is less invasive, reducing morbidity. Moreover it allows an easy concomitant treatment of associated deformity such as shortening and axial or rotational malalignment. On the other hand it requires a good compliance and active involvement of the patient for daily adjustments of the fixator, meticulous pin care and intensive

■ Johan Lammens, MD PhD, Orthopaedic Surgeon.
■ Johan Vanlauwe, MD, Orthopaedic Surgeon.
Universitair Ziekenhuis Pellenberg, KU Leuven, Belgium.
Correspondence : Johan Lammens, Department of Orthopaedic Surgery, Universitair Ziekenhuis Pellenberg, Weligerveld 1, 3212 Pellenberg, Belgium.
E-mail : johan.lammens@uz.kuleuven.ac.be

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physiotherapy, but the patient is usually rewarded with an excellent result.

PATIENTS AND METHODS

All records of healing problems in femoral fractures were studied. Only the records of patients with a diaphyseal fracture or osteotomy treated with reamed intramedullary nailing, either primarily or as an exchange procedure, but leading to a non-union, were collected and subjected to detailed analysis. There were six male and two female patients, with a mean age of 40 years (range : 18-64). The aetiology was a motor vehicle accident on six occasions and a fall from a roof in one patient. One patient had undergone a corrective osteotomy for a rotational deformity after a fracture she had sustained in a road traffic accident.

The reamed nailing was performed as a single primary procedure in only three subjects. Among the other five patients, three had twice a nailing procedure, with additional bone grafting in two of them, and one patient underwent a plate fixation followed by nailing. In two patients the nails were broken, thereby dynamising the fracture, and in two others the dynamisation had been performed to stimulate fracture healing (table I). Only these two patients presented within one year after the fracture because of increasing pain and instability and could be considered to have a delayed union. The others had a definite non-union as their delay to presentation was between one and three years since the onset of the problem.

The diagnosis of delayed union or non-union was based on pain with weight bearing or mechanical stress over the fracture, and on the absence of definitive fracture bridging on four radiographs with different incidences, complemented in some occasions with stress radiographs.

A careful clinical examination was performed in all patients to evaluate hip and knee function and to exclude shortening, axial or rotational malalignment. A full leg teleradiograph in anteroposterior and lateral incidence was taken in every patient. There were no major limitations of hip or knee function but associated deformity was diagnosed in six patients (table I). In two patients the nail was broken at the most proximal of the two distal screw holes.

At the operation the hardware was removed with the exception of the distal fragments of the two broken nails. A standard Ilizarov frame according to Cattaneo *et al* was applied in all patients but with one extra ring in those with concomitant shortening, as two simultaneous manoeuvres were to be combined during the treatment (*4*). Positioning of the rings in the two patients with the broken nail fragment *in situ* did not pose any problem, as previously described by the authors (*12*). If an additional distraction had to be performed a standard percutaneous osteotomy as for simple leg lengthening was done

Table I. — Representation of the eight patients

Patient	Age/Sex	Concomitant deformity	Previous surgery	Remark	Treatment	Total healing time (days)
DP	38 M	heterolateral shortening 1.5 cm	2 × nail bone graft		unifocal compression	130
LG	64 M	valgus shortening 2 cm	dynamisation		bifocal	192
VE	18 F	varus, internal rotation	2 × nail bone graft	broken nail	unifocal correction and compression	154
VT	64 M			broken nail	unifocal compression	288
VE	28 M	varus shortening 6.5 cm	external fixator 2 × nail	partial plexus lesion	bifocal	392
VA	43 F	internal rotation	plate nail		unifocal correction and compression	255
VB	43 M		dynamisation		unifocal compression	210
WF	22 M	shortening 2.5 cm	2 × nail		bifocal	156

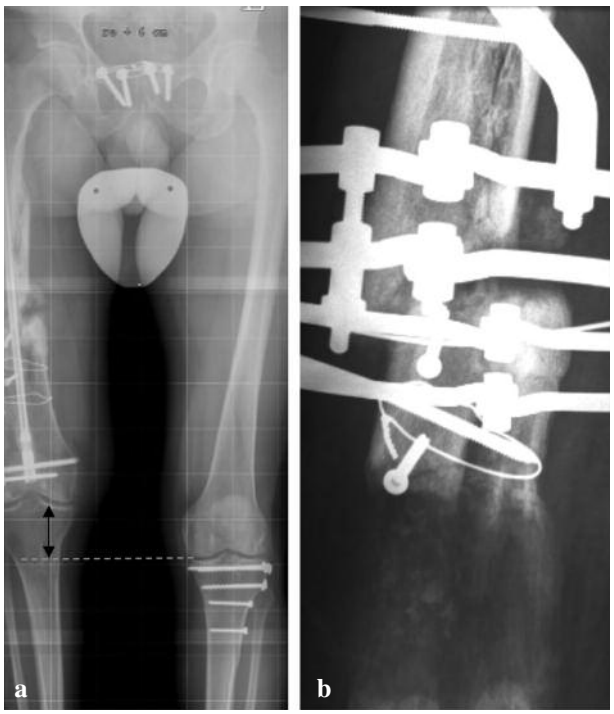

Fig. 1. — Non-union at mid-diaphyseal level with 6.5 cm shortening (a) treated with compression at level of non-union and distal distraction (b).

Fig. 2. — Final healing with consolidation of non-union and completely remodelled distraction area.

Fig. 3. — Illustration of the mechanotransduction principle with progressive callus formation during gradual compression after removal of the nail at 4 (a) and10 (b) weeks with final healing at 7 months (c) and further remodelling at one and a half year (d).

Fig. 4. — Painful non-union at sixteen months post trauma. Manipulation under traction shows slight movement of the distal fragment due to nail fracture at the level of the proximal hole.

through a two centimetre incision in the supracondylar area.

Postoperatively weight bearing was encouraged from the second postoperative day on, and gradual compression initiated in all patients at a rate of twice 0.25 mm per day. The three patients who needed a lengthening started the additional gradual adaptation of their osteotomy at postoperative day 7, at a rate of 0.75 mm per day. Follow-up with radiographic control was done at two week intervals. If cortical bridging was visible on at least one incidence, the circular frame was reduced to a simple unilateral fixator under a short general anaesthesia. Removal of the frame was carried out if complete consolidation was visible as cortical bridging of at least three cortices on four radiological incidences or on CT scan with sagittal and frontal reconstruction images. After removal of the external fixator no further protection was used and physiotherapy continued till knee flexion reached at least 90°.

Fig. 5. — Non-union under compression (a) and final healing (b) with distal nail fragment *in situ.*

RESULTS

Consolidation was obtained in all patients at an average of 32 weeks (222 days, range : 154-392). At this stage complete union was visible on the radiographs, on some occasions comfirmed with a CT-scan. On full leg the mechanical axis was restored within normal limits (central to 10 mm medial) and leg length difference was limited to a maximum of one centimetre (*15*). At the last follow-up visit, at least one year after removal of the fixator, all patients had a minimum of 120° of knee flexion. Hip mobility was within normal ranges, except for the two patients over sixty years old, who had limitation of internal rotation, but this was similar to the contralateral side and was considered unrelated to the femoral problem. In two patients there was still a gait disturbance : one patient walked with a slight Trendelenburg sign due to weakness of the gluteal muscles and one had a dropfoot due to his concomitant partial plexus lesion at the time of the initial trauma. Moreover, this patient also had ipsilateral knee instability due to a posterior cruciate ligament rupture, for which a repair was subsequently performed. In all patients the scars had healed completely and there were no pin site related problems.

DISCUSSION

Since the eighties the Ilizarov method has been added to our treatment tools for non-unions because of its unlimited possibilities in manipulating long bones. Simple compression, a combination of compression and distraction for realignment or lengthening, or a compression with a distraction at a distant focus, promote bone healing and often permit to cure the pseudarthrosis without the need for bone grafting. In the most complicated cases with bone loss, such as infected or multi-operated non-unions with defects, reconstructions are possible by performing a bone transport. Despite its reputation as the method of last hope after several previous failures, and thus rather used as an exceptional treatment modality and not as a standard of care, large series of patients with an excellent outcome were reported in literature, especially in tibial and humeral healing problems (*5,9,11,17*). Due to the lower frequency of femoral non-unions and the better healing response after repeated nailing, the Ilizarov method appears less popular for this type of problem, although its successful application has been reported numerous times, with a special recommendation for infected non-unions (*2,16*).

This review indicates that less complicated cases also respond very well to an Ilizarov treatment, thereby illustrating two important principles.

First of all it demonstrates that in a relatively undisturbed biological surrounding, the modification of the mechanical parameters can solve the problem. It is not only the restoration of the stability, but also the gradual compression exerted that stimulates the healing, through principles of mechanotransduction. The latter is not fully understood yet, but recent work in the domain of mechanobiology is discovering the complex world of mechanosensation leading to induction of mediating signaling molecules in osteoblasts and osteoclasts, activating important intracellular signal transduction pathways (*10*). Many growth factors are upregulated by mechanical stimulation, such as vascular endothelial growth factor (VEGF), insulin-like growth factor (IGF) I and II, transforming growth factor bêta (TGFβ) 1 and bone morphogenetic proteins (BMP) which in turn activate cascades as e. g. phosphatidylinositol 3 kinase, mitogen activated protein kinase (MAPK) and SMADs, regulating cell behaviour by turning on and off gene activity (*13*).

Secondly, and this maybe in contrast to many surgeons' opinion, it proves that non-union treatment does not necessarily include bone grafting. The philosophy of using autologous bone is that it adds both a structural support (conductive aspect) as well as a biological booster by supplying bone cells and growth factors (inductive influence). This gold standard approach has withstood the test of time as it has been used for many decades throughout the world with overall good results. However it should not be forgotten that the biology of difficult healing fractures is often not destroyed, in particular in case of hypertrophic non-unions. Even in situations where a pseudoarthrosis is considered atrophic, some biological potential is left, as demonstrated by immunohistochemical analysis of growth factors in human pseudoarthrosis tissue samples (*8*). Despite advances in molecular biology we have not reached the stage yet that non-unions can be screened for their biological potential. So far this can only be estimated by indirect parameters such as the general conditions of the patient, with special attention for age, diseases, use of drugs and nicotine, the type of fracture (closed versus open, multioperated or not, good or bad soft tissue covering, absence or presence of infection), and the radiographic aspects (good quality of bone ends versus sclerosis or osteolysis). This combination of general and local parameters enables us to some extent to trace good candidates for simple compression treatment of a non-union.

Uncomplicated femoral non-unions after previous intramedullary nailing in healthy adults seem to belong to this category as they show enough biological response under an improved mechanical situation. In case of an additional osteotomy for restoration of the length or axis, an extra stimulus is added to the local biology by increasing the blood flow throughout the limb, as already illustrated forty years ago by Ilizarov (*18*).

Extra stability to the system can be added by leaving the nail *in situ*, building the Ilizarov frame around it, as described by Brinker but this does not

seem to be essential, as illustrated in this series (*2*). Moreover this has several drawbacks as it is more difficult to position the frame, axial or rotational correction is not easy to perform and making a new osteotomy around the nail for lengthening is an additional difficulty. Furthermore it is not applicable with a broken nail due to the lack of compression that can be exerted, in the case that the nonunion is at the level of the fractured nail with bone resorption around both bony fragments, resulting in a metal on metal compression. And last but not least there might be a risk for infection of the nail.

Therefore we generally recommend to remove the nail, the only exception being the distal part of a broken nail, which is often difficult to extract, and does not prevent compression or correction, as previously described by the authors (*12*).

CONCLUSION

The Ilizarov method is a reliable tool for treating healing problems after femoral nailing. Consolidation and concomitant deformity correction and lengthening if necessary are obtained, without the need for bone grafting. The biological potential after reamed intramedullary nailing is still sufficient to allow progressive callus formation under conditions of stable fixation and gradual compression.

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