The Illizarov Method in Infected Non-union of Long Bones

REC Rose, W St O Palmer

ABSTRACT

Objective: *To review the results of the management of infected non-union of long bones using the Illizarov fixator.*
Methods: *Eight patients with non-union of long bones associated with current or prior infection were treated between 1998 and 2006. Seven patients were treated between 2004 and 2006. There were seven males and one female with an average age of 32 years (range 17–53 years). Four non-unions were located in the tibia, two were present in the humerus, one was present in the femur and one was intra-articular. Five non-unions were treated with acute compression, two were treated with bone transport and the frame was used in a static mode in one.*
Results: *There was one excellent, three good, one fair and three poor results.*
Conclusion: *The Illizarov technique is an important treatment method for surgeons performing post-traumatic reconstructive surgery. Non-union, infection, shortening and deformity are all addressed simultaneously.*

El Método Illizarov en la no Unión Infectada de los Huesos Largos

REC Rose, W St O Palmer

RESUMEN

Objetivo: *Examinar los resultados del tratamiento de la nounión infectada de los huesos largos usando el fijador de Illizarov.*
Métodos: *Ocho pacientes con nounión de huesos largos asociada con infecciones presentes o previas fueron tratados entre 1998 y 2006. Siete pacientes fueron tratados entre 2004 y 2006. Hubo siete varones y una hembra con edad promedio de 32 años (rango 17–53 años). Cuatro nouniones estaban localizadas en la tibia, dos se hallaban presentes en el húmero, una se encontraba en el fémur y otra era intra-articular. Cinco nouniones fueron tratadas con compresión aguda, dos fueron tratados con transporte óseo, y en uno se usó el aparato de un modo estático,*
Resultados: *Hubo un resultado excelente, tres buenos, uno aceptable y tres resultados pobres.*
Conclusión: *La técnica de Illizarov es un importante método de tratamiento para los cirujanos que realizan cirugía reconstructiva post-traumática. Nounión, infección, acortamiento, y deformidad, pueden ser todos abordados simultáneamente.*

West Indian Med J 2007; 56 (3): 246

INTRODUCTION

The treatment of infected non-union of long bones has always been a challenge for orthopaedic surgeons. The problems in infected non-union include osteomyelitis, bone and soft tissue loss, osteopenia, multiple sinuses, adjacent joint stiffness, complex deformities and limb-length discrepancies. These factors make an unfavourable milieu for fracture union (1). A fracture that had been ununited for less than six months was defined as a non-union if the wound was open and infected, and there was exposed dead bone or metal (2). A fracture was also considered a non-union if, after six months, there was clinically apparent motion at the site of the fracture; formation of a sinus, indicating the presence of dead bone, or extensive osteomyelitis (2).

The goal of treatment is a well-aligned, healed, painless and functional limb (3). This can best be achieved by thorough and adequate debridement, stabilization of the fracture, soft tissue coverage and reconstruction of the bony defect (4, 5). Corticocancellous bone graft (4, 6), vascularized bone graft (7), non-vascularized fibula (8), distraction osteogenesis (Ilizarov technique) (2, 9, 10), posterolateral

From: Division of Orthopaedics, Department of Surgery, Radiology, Anaesthesia and Intensive Care, The University of the West Indies, Kingston 7, Jamaica, West Indies.

Correspondence: Dr REC Rose, Division of Orthopaedics, Department of Surgery, Radiology, Anaesthesia and Intensive Care, The University of the West Indies, Kingston 7, Jamaica, West Indies. E-mail: recrose@hotmail.com.

bone graft (11), and fibula pro-tibia (transfer of the ipsilateral fibula) (3, 12) are several treatment options described for infected non-union with or without bone loss.

The techniques of Illizarov have been popular for the treatment of infected non-unions of long bones.

This article describes the author's experience in treating patients with tibial, humeral and femoral non-unions with the Illizarov frame.

SUBJECTS AND METHODS

Eight patients with non-unions of long bones associated with current or prior infection were treated by one surgeon between 1998 and 2006. Seven patients were treated between 2004 and 2006. All patients were treated with the Illizarov technique. Five patients were initially managed at the University Hospital of the West Indies; the other three had been treated elsewhere initially and were subsequently referred for management of the non-union and infection.

There were seven males and one female with an average age of 32 years (range 17 –53 years). Four non-unions were located in the tibia, two were present in the humerus, one was present in the femur and one was intra-articular (tibial plateau fracture).

The mechanism of the initial injury was motor vehicle accidents in six patients, a motor cycle accident in one patient and a fall in one patient. Four injuries were closed, and four were associated with an open wound. The wounds were classified according to the system of Gustilo and Anderson as Type 3A in one patient, Type 3B in two patients and Type 3C in one patient (Table 1). All of the patients with open injuries were initially treated with serial wound debridement, parenteral antibiotics and application of external fixation. Four patients had their closed fractures treated with open reduction and internal fixation using plates and screws. Infection developed after the initial injury in the four patients with open wounds, and after the first surgery in three patients with closed injuries. One patient developed an infection following replating of the humerus. The internal fixations were removed once the infection was confirmed and the fractures were stabilized with a ring fixator in three patients and a cast in one patient. Gentamicin beads were inserted in three of these four patients following removal of the plates and screws and adequate debridement. Five patients were managed with excision of intervening fibrous tissue and infected dead bone to expose fresh bleeding bone ends, which were approximated and acutely compressed with the Illizarov fixator (Table 2). Autogenous bone graft was harvested from the iliac crest and applied at the time of acute compression in four of the five patients. The rate of compression was 0.25 mm daily for two weeks, then 0.25 mm every other day until there was radiological evidence of union (Fig. 1). The following were the non-union sites in the five patients who were treated with acute shortening: the humerus was involved in two patients, the tibia in two patients and the femur in one patient. The two patients with humeral non-unions (Cases 7, 8) had 3 cm and 2 cm of shortening following acute compression (Fig. 2). Lengthening was not performed in these patients. Following acute shortening, two (Cases 2, 6) of the other three patients had 5 cm each of shortening, and the other patient had a discrepancy of 2 cm. Lengthening was

Table 1: Pre-operative data for eight patients with infected non-union

Case	Age (years)/ Gender	Involved bone	Injury	Original wound mechanism
1	17 M	Tibial diaphysis	MVA	Closed
2	53 M	Tibial diaphysis	MVA	Open Type 3B
3	39 M	Tibial diaphysis	MVA	Open Type 3C
4	23 M	Tibial diaphysis	MVA	Open Type 3B
5	40 M	Tibial plateau	MVA	Closed
6	19 M	Femoral diaphysis	Fell from height	Open Type 3A
7	18 F	Distal 1/3 humerus	MVA	Closed
8	45 M	Humeral diaphysis	MVA	Closed

Table 2: Data for the eight patients treated with the Illizarov method for non-union

Case	Bony defect after debridement (cm)	Treatment method	Time in frame (months)	Follow-up (months)	Number of operations	Time to index Illizarov surgery (months)
1	4	Transport	8	2	5	2
2	5	Compression	10	24	4	6
3	2	Compression	8	4	3	7
4	8	Transport	16	6	4	6
5	2	Static frame	8	3	4	3
6	5	Compression	8	7	3	3
7	2	Compression	3	19	4	9
8	3	Compression	16	2	8	6

planned as a staged procedure in the two patients with 5cm of shortening because of the severity of soft tissue and bony infection. Following eradication of the infection and the attainment of bone union, one of the two patients is presently awaiting lengthening, but the other had declined further surgery. Two patients had debridement (Cases 1, 4), application of the frame, proximal metaphyseal osteotomy and bone transport to close the tibial defects (Fig. 3). The gentamicin beads were removed at the time of acute compression in two patients, and bone transport in one patient. Following application of the frame, physiotherapy was commenced to prevent further contractures of the joints. Seven of the eight patients had joint stiffness prior to application of the Illizarov frame.

The one patient (Case 5) with the infected tibial plateau fracture non-union underwent debridement of the patellar tendon, bone and overlying soft tissue. The Illizarov frame was applied to the tibia and was extended across the knee to stabilize both the fracture and the joint. A musculocutaneous flap was used to cover the area of the soft tissue loss.

The eight patients had an average of four operations (range 3–8 operations) for treatment of the original fracture and the non-union. The average bony defect following debridement was 3.8cm (range 2–8cm). Patients spent an average of 9.6 months in the fixator (range 3–16 months). The interval from the initial treatment to the index Illizarov treatment averaged five months (range 2–9 months).

RESULTS

The patients were followed-up for an average of fourteen months (range 2–48 months). The results were divided into bone and functional results, according to the classification of the Association for the Study and Application of the Method of Illizarov (13, 14). This classification is applicable for tibial and femoral non-unions.

Table 3 details the bone results as determined according to four criteria: union, infection, deformity and limb-length discrepancy (13, 14). A fracture was considered to be united when there was no motion at the fracture site following removal of the Illizarov frame and when there was radiological evidence of union. The fracture united in five patients with one treatment and there were no refractures following removal of the frame. The time to union ranged from eight months to sixteen months (average 10 months). The tibial plateau fracture did not unite after eight months in the frame. The angular deformities and limb length inequalities are listed in Table 3. Superficial pin-tract infections developed in all patients; these resolved with local care and oral antibiotics. In one patient, a half-pin was removed and in another patient a single wire was repositioned. Five of the six patients were free of infection at the latest follow-up visit. The osteomyelitis of the tibial plateau did not resolve and the frame was removed at the patient's request. The knee was then immobilized in a long-leg cast.

Table 3: Bone results according to the classification of the Association for the Study and Application of the Method of Illizarov; applicable for tibial and femoral non-unions

Case	Union	Infection	Deformity	Limb-length discrepancy (cm)	Result
1	Yes	No	3°	Nil	Excellent
2	Yes	No	5°	5	Good
3	Yes	No	9°	2	Good
4	Yes	No	6°	1.5	Good
5	No	Yes	Nil	2	Poor
6	Yes	No	15°	5	Fair

According to the protocol of the Association for the Study and Application of the Method of Illizarov, a bone result cannot be graded excellent unless union was achieved without the use of a bone graft. An excellent result was defined as union, no infection, deformity of less than 7° and a limb-length discrepancy of less than 2.5cm. A good result was defined as union and any two of the other three criteria; a fair result, as union and one of the other criteria; and a poor result, as non-union or refracture, or as union but none of the remaining three criteria. The authors used the above classification to evaluate the results of the tibial and femoral non-unions. According to the system, the bone results were excellent in one patient, good in three patients, fair in one patient and poor in one patient (Table 3).

The functional results were based on five criteria (Table 4): a significant limp, stiffness of either the knee or the ankle (loss of more than 15° of full extension of the knee or 15° of dorsiflexion of the ankle in comparison with the normal contralateral ankle), soft tissue sympathetic dystrophy, pain that reduced activity or disturbed sleep and inactivity (unemployment or an inability to return to daily activities because of the injury). The functional results were considered excellent if the patient was active and none of the other four criteria were applicable; good, if the patient was active but one or two of the other criteria were applicable; fair, if the patient was active but three or four of the other criteria were applicable, and poor, if the patient was inactive regardless of whether other criteria were applicable. Four patients were able to return to work and daily activities. Four patients had an obvious limp and one had persistent pain. According to these criteria, the functional result was excellent in one patient, good in three patients and poor in two patients (Table 4).

The functional results of the two humeral non-unions (Cases 7, 8) were expressed according to Stewart and Hundley (15) (Table 5). One patient was assessed as having a fair result because there was limitation of elbow flexion and extension of less than forty degrees. The other patient (Case 8) had a poor result due to refracture subsequent to a fall. A sinus was observed at the level of the fracture site. At exploration of the fracture site, pus was noticed. Debridement, insertion of gentamicin beads and application of the Illizarov frame were performed. This patient is still being treated.

Table 4: Functional results according to the classification of the Association for the Study and Application of the Method of Illizarov; applicable for tibial and femoral non-unions

Case	Significant limp	Joint stiffness	Soft tissue sympathetic dystrophy	Pain	Able to perform daily activities	Result
1	No	No	No	No	Yes	Excellent
2	Yes	Yes	No	No	Yes	Good
3	No	Yes	No	No	Yes	Good
4	Yes	Yes	No	No	Yes	Good
5	Yes	Yes	No	Yes	No	Poor
6	Yes	Yes	No	No	No	Poor

Table 5: Functional results for humeral non-union according to Stewart and Hundley criteria

Score	Pain	Limitation of elbow or shoulder mobility (°)	Angulation (°)	Result
Good	No	< 20	< 10	None
Fair	After efforts or fatigue	20–40	> 10	1
Poor	Permanent	> 40	Radiologic non-union	1

DISCUSSION

Infected non-union is one of the most difficult clinical situations despite major advances in the fixation technique, soft tissue management and antibiotic therapy (16). The infection is likely to be eradicated if all of the necrotic bone is resected completely. However, extensive resection usually leaves a large gap between the fragments. Furthermore, a non-union that is associated with an infection is almost always also associated with deformity, limb-length discrepancy, joint stiffness, disuse osteoporosis and soft tissue atrophy. The Ilizarov method simultaneously addresses non-union, infection, shortening, deformity and osteoporosis (2, 9, 10, 13–15). Acute shortening was performed in five patients and bone transport in two patients. In one patient, the frame was applied to stabilize the ununited tibial plateau fracture and the knee joint.

Acute shortening can be accomplished safely for defects up to 3 to 4cm in the tibia and up to 5 to 7 cm in the femur (17). Acute or gradual shortening offers advantages over transport by decreasing tension and gaps in the open wound, shortening the length of time in the frame and is recommended in patients with diabetes mellitus, severe peripheral vascular disease and connective tissue disorders (18). Acute shortening of more than 4cm in the tibia can cause the development of tortuous vasculature and actually produce a low flow state with detrimental results. Open soft tissue wounds when acutely compressed can become bunched and dysvascular, with the development of significant oedema and the possibility of additional tissue necrosis and infection (19, 20). More than 4 cm may be safely accomplished in the femur; however, similar problems with wound oedema and bunching may occur (21). It has been shown that femoral shortening greater than 5 cm can result in occasional permanent extensor weakness (22). The closer the acute shortening is to the knee, the greater is the effect it will have on the extensor mechanism. If the defect is larger than can safely be closed acutely, gradual shortening can accomplish the same goals. Shortening at a rate of 0.5cm per day in divided doses will rapidly oppose the skeletal defect as well as avoid the detrimental soft tissue consequences and vascular kinking of acute compression (23). In the two patients with 5cm defects, the author preferred to perform lengthening after the active infection was eradicated. The patients in whom acute shortenings were performed, had bone defects ranging from 2 to 5 cm. Patients with massive defects, greater than eight to 10 cm, were candidates for gradual compression and bone transport (18, 21, 24). No complications were noted following acute compression of the two patients with the 5cm limb discrepancies.

Most diaphyseal fractures of the humerus heal without surgical intervention (25). Non-union after conservative management can be successfully treated by various surgical methods. These include open reduction and internal fixation with plates and screws, reamed intra-medullary nailing and external fixation (26, 27, 28). Failure to unite after surgical treatment may be due to poor contact between the bone ends, inadequate stabilization, devitalized bone, osteopenia and bone defects. When there are the additional complications of poor soft tissue or infection, treatment by conventional methods of internal fixation becomes very difficult. Two patients in this review developed osteomyelitis following plating of the humerus for diaphyseal fractures. Both patients had surgical debridement and insertion of gentamicin beads following removal of the internal fixation. In order to allow movement of the shoulder and elbow, the Illizarov frame was constructed with circular rings around the diaphysis and semicircular rings around the proximal and distal ends of the humerus. The non-union sites were then compressed.

Bone union occurred in six of the eight patients with one treatment. There was one refracture. Autogenous bone grafts were applied in four patients at the time of acute shortening. Many authors, however, have reported bone union without bone grafting (29, 30). Two patients had bone transport to close a 4 cm and 8 cm tibial defect. The patient with the 8 cm tibial defect had the bone ends debrided and freshened before they were docked in compression. Autogenous iliac crest graft was applied to the docking site to aid in healing. Docking site augmentation has been shown to decrease the overall rate of non-union and decrease the time in the frame (9, 24, 31). Dendrinos *et al* (2), however, performed distraction osteogenesis in 28 patients and achieved union in 14 patients without grafting the docking site.

Significant limb-length inequalities were present in two patients, each with 5 cm discrepancy. One patient declined further surgery while the other is awaiting lengthening. Bone deficits less than 5 cm can be acutely shortened in the humerus without the patient experiencing any functional deficits (30). The 2 cm of shortening in the humerus in each patient was not lengthened.

Infected intra-articular non-unions are difficult to treat because they often lack a large fragment of bone for fixation. In the patient with the tibial plateau fracture, the circular fixator was used in a static mode. The fracture did not unite and the infection remained unresolved. The patient was lost to follow-up after removal of the frame.

In the six patients whose results were evaluated according to the Association for the Study and Application of the Method of Illizarov, the functional results were inferior to the bone results. Bone union does not guarantee a good functional result. Two of the patients had poor results due to inability to work and perform daily activities, even though the bone was healed in one patient.

According to the Stewart and Hundley classification (15) for humeral non-unions, there was one fair and one poor result. Case 7 was evaluated as having a fair result even though there was bony union. This patient had limitation in elbow mobility. The other patient (Case 8) was assessed as having a poor result due to refracture subsequent to a fall after removal of the frame.

The techniques of Illizarov remain an important treatment method for surgeons performing post-traumatic reconstructive surgery, particularly in situations with no good alternatives, such as osteomyelitis, osteopenia, complex deformities and significant limb-length inequalities. The drawbacks of this method are the time and resource intensive nature of treatment, the difficulties of prolonged fixator use and the potential of major and minor complications.

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