ILIZAROV TREATMENT OF TIBIAL NONUNIONS RESULTS IN 16 CASES

M. B. LAURSEN, P. LASS, K. S. CHRISTENSEN

Treatment with the Ilizarov technique was performed in 16 patients with complex tibial nonunions. Two years post treatment the functional stage and patient satisfaction were recorded. There were 4 hypertrophic, 3 atrophic and 9 infected nonunions. Eleven patients had segmental bone loss.

Fifteen nonunions united, and limb length discrepancy was reduced within 1.5 cm of the contralateral leg. Average time in the frame was 182 days. Fifteen of the 16 patients were satisfied with the treatment. One patient demanded an amputation after 3 months of treatment, despite good signs of healing. There were no refractures or recurrent infections.

In conclusion the Ilizarov technique for complex nonunions has a high rate of success in achieving union and eradicating infection, bone loss and malalignment. The treatment is demanding both to the surgeon and to the patient, but we strongly recommend the Ilizarov treatment for tibial nonunion, especially in cases with chronic infection and severe bone loss.

Keywords : tibial fractures ; pseudarthrosis ; Ilizarov technique.

Mots-clés : fracture du tibia ; pseudarthrose ; technique d'Ilizarov.

INTRODUCTION

Although several methods for treatment of tibial nonunion have been successful (18), it is still a great challenge for the orthopedic surgeon. After several operations, long periods of immobilization and extended rehabilitation, amputation may still be the outcome. The treatment of tibial nonunion by distraction osteogenesis stimulates the osteogenic factors (8, 9, 15). Furthermore this method has the potential to address a coinciding deformity, shortening or infection, while achieving union (1, 2, 16). Ilizarov et al. have reported excellent results concerning the treatment of bone defects following decades of experience and scientific work (8, 9, 15), and the few Western reports until now show success in 96% to 100% of the patients. (2, 4, 16). This study is a review of the first 16 patients treated for tibial nonunion by the Ilizarov method in our department. The aim of this study is to evaluate the treatment and to describe its possibilities.

PATIENTS AND METHODS

Sixteen patients suffering from tibial nonunion for six months or more were treated consecutively from October 1991 through November 1995. There were five women and eleven men with an average age of 36 years (range, 10 to 56 years) at the initial operation. Eleven fractures were open and five were closed. Patient characteristics concerning primary injury and previous treatment are summarized in table I.

Three patients need further explanation. Case 1 had a traumatic loss of the distal 13 cm. of the tibia, but the fragment was brought with him when he was admitted to the hospital. The bone was cleaned and frozen, and later an attempt at reimplantation was done (fig. 1). The graft was removed at the initial operation (fig. 2). Case 2 lost

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Table I. — Patient characteristics concerning primary injury and treatment

No	Age	Sex	Trauma	Fracture Type (Gustillo)	Additional	Fracture care	Surgeries	Bone grafts
1	12	M	MVA	III-C comminuted	bone loss	ext	13	2
2	15	F	MVA	III-B midshaft	muscle loss	ext	9	2
3	9	F	Heavy	III-C comminuted	bone loss	ext	4	1
4	48	M	MVA	III-A comminuted	–	ext	4	0
5	40	M	Heavy	I butterfly fragment	–	int	5	2
6	56	M	Fall	I comminuted pilon	–	ext	1	0
7	38	F	Fall on street	closed midshaft + ankle	–	ext	10	1
8	43	M	Fall	I comminuted	–	int	1	1
9	16	M	MVA	closed butterfly	–	int	4	1
10	18	M	Sports	closed midshaft	–	ext	6	0
11	51	F	Sports	closed spiral	–	int	2	0
12	24	M	MVA	III-A distal	ankle luxation	int	10	1
13	21	M	MVA	II comminuted	–	ext	5	0
14	49	M	MVA	closed butterfly	compart. syndrome	ext	10	2
15	51	M	Jump	III-A comminuted pilon	–	int	2	0
16	49	M	Heavy	II comminuted	–	ext	4	1

Heavy, Accident involving heavy machinery. Fall, fall from higher level. MVA, motor vehicle accident. Fracture care, type of fracture care after the primary injury : Ext, external fixation. Int, internal fixation (intramedullary nail or plate and screws). Surgeries, number of surgeries between primary injury and index operation. Bone grafts, number of bone grafts between primary injury and index operation.

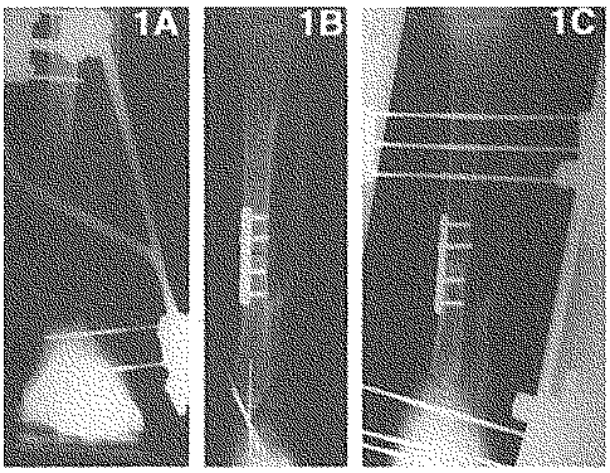

Fig. 1. — Xrays of case 1. A : After initial external fixation. (distal 1/3 of tibia was kept in the freezer). B : The frozen bone was reimplanted and internally fixated. C : Four months later the distal fragment was infected, screws were loose and the fracture still not united.

both the extensor and peroneal muscle groups and their nerves and vessels initially. Case 3 had a traumatic bone loss of 2 cm. at the initial trauma and a further resection of 6.5 cm. of atrophied bone at the initial operation.

The patients had suffered from their fractures and complications for an average of 27 months (range, 7 to 180 months). At the initial operation, 12 nonunions were atrophic without callus formation, often combined with bone resorption. Nine of these also were infected. Four patients had hypertrophic nonunions, with formation of a large volume of callus around the fracture site (table II). All patients had a stable fixation, obtained by an Ilizarov external fixation frame, offering the possibility of a three-dimensional adjustment. The frames were designed individually for each patient, after thorough clinical and radiological examination. For the first 10 procedures the frames were prepared in advance, to reduce operating time ; with growing experience the frames were built on the patient during surgery. The bones were transfixed inside the frame using 1.8 mm. wires, with and without olives tightened to 110 kilograms using a wire tensiometer. Supplementary 5 mm. threaded half-pins were used for fixation in diaphyseal areas to avoid soft tissue problems with transfixing wires on the back of the leg. Seven patients had nonunions in the distal part of tibia without possibility to put two rings on the distal fragment ; in these cases it was necessary to apply one or two half rings around the foot fixed with two wires in the calcaneus to obtain stability of the frame.

All patients received a single dose of penicillinase resistant penicillin (methicillin®) intravenously, as routine prophylaxis during the operation. In cases suspected of deep tissue infection, samples were collected by

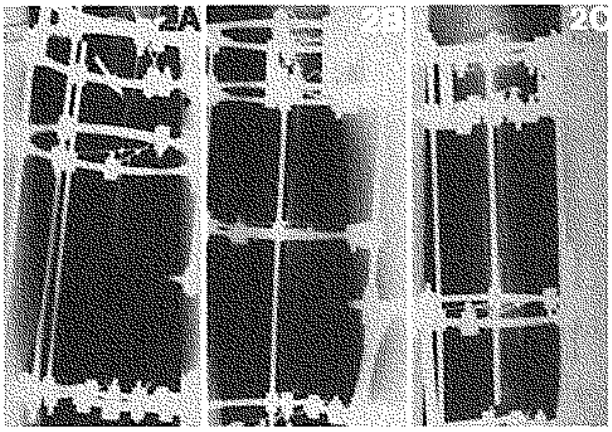

Fig. 2. — Xrays of case 1. A : The infected bone was removed and the Ilizarov frame was applied. This frame consisted of 2 proximal rings fixed to the proximal part of tibia with 2 wires each, one transportation ring fixed to the tibial shaft with 2 olive wires and distally there is a special arrangement of 2 half rings perpendicular to each other ; one behind the heel and one around the tarsus (the latter is not visible in this xray). The arrow points to the corticotomy between ring 2 and ring 3. B : Xray control during bone transportation. The tibial shaft connected to the transportation ring is "travelling" from the corticotomy towards the "docking-site". Note the "snow" formation in the distraction gap, indicating the formation of new bone. C : The distal end of the tibial shaft has reached "docking-site" (here the dome of talus). The regenerate in the distraction gap is consolidating.

the method of Kamme-Lindberg (10) prior to infusion of antibiotics, and the methicillin® treatment was continued until it could be modified according to the microbiological findings.

The strategy for the treatment depended on the type of nonunion and the amount of bone loss. The possibilities are summarized in table III and illustrated in figure 2. All the atrophic nonunions were revised ; in cases suspected of infection it was done open and radically. Cases without infection had a minimally invasive refreshing of the bone ends. Seven patients had a classical Ilizarov corticotomy in the proximal part of the tibia (fig. 2A). This procedure brings the same osteogenic stimulus to a fracture or nonunion as a routine cancellous bone graft (9, 15). Hinges were used in frames for patients with hypertrophic nonunions with angulation. The latter was gradually corrected by distraction on the concave side of the deformity. As soon as alignment was achieved, the hinges were replaced by rods, to secure frame stability. After the surgery there were no changes for seven days ; thereafter all manipulations were done by the patients themselves by turning nuts on the fixator apparatus four times a day, resulting in movement in the axis of the bone of one mm. per day. Internal bone transport was performed in five cases with severe bone loss. The bone segment between the nonunion and the corticotomy was moved distally. When the bone segment

Table II. — Ilizarov treatment

No.	Fracture age (m)	Nonunion type	Infection	Bone loss (mm)	Corticotomy	Lengthening (mm)	Fixator time (days)	HI (days / cm)	Complications
1	29	Atrophic	+	130	+	90	214	24	1p
2	15	Atrophic	+	55	+	60	257	43	1p, 1minor
3	8	Atrophic	+	85	+	85	211	25	1p
4	12	Hyper.	–	15	–	15	122	81	1p
5	180	Atrophic	–	0	–	0	106	–	1major
6	6	Atrophic	–	0	–	0	104	–	–
7	19	Atrophic	+	30	+	35	233	67	1p, 2o
8	7	Atrophic	+	0	–	0	122	–	1p
9	13	Hyper.	–	20	–	20	100	50	–
10	36	Atrophic	+	0	–	0	156	–	2p, 1o
11	21	Hyper.	–	0	–	0	250	–	1p, 1o
12	33	Atrophic	+	65	+	53	304	57	–
13	13	Atrophic	+	40	+	40	169	42	1p
14	12	Hyper.	–	6	–	6	119	198	1p, 2o
15	31	Atrophic	–	90	+	90	298	33	1p
16	27	Atrophic	+	35	–	0	143	–	1p, 1o

Bone loss : includes necessary resection at the index operation. HI, healing index, Complications : number of p : problems, o : obstacles, minor : minor true complications, major : major true complications.

Table III. — Treatment strategies

Nonunion type		Operative applications	Postoperative treatment
Hypertrophic	no shortening	Ilizarov frame no revision	Stability
	+ shortening	no grafting no corticotomy	+ lengthening in nonunion
	no shortening + angulation	+ hinges	+ gradual correction
	+ shortening + angulation		+ rearranging of frame
Atrophic	no shortening	Ilizarov frame + revision + acute correction of angular deformities no grafting no corticotomy	Stability + "accordion maneuver"
		+ grafting	
	+ shortening	+ corticotomy no grafting	+ lengthening in corticotomy
		+ grafting + corticotomy	
Large defects		Ilizarov frame + revision + corticotomy no grafting	Stability + internal transport + rearranging of frame + "accordion maneuver"
			+ grafting at docking-site

reached the former nonunion site, hereafter named "docking-site", one patient had additional surgery for refreshing of bone ends and cancellous bone grafting. Others had an "accordion maneuver" to stimulate healing at the docking-site. After docking further lengthening could still be achieved by distraction of the corticotomy.

The "accordion maneuver" is a combination of distraction and compression, where treatment alternated between a week of distraction and a week of compression, until callus formation was visible on xray (15, 16).

For further stimulation of bone healing early weight bearing was encouraged if possible from the first postoperative day ; the cases with angulation had to wait until the hinges were replaced. Intensive physiotherapy to maintain or to regain normal range of motion of the knee and ankle joints was considered an important part of the treatment. Consolidation of the regenerate bone was considered sufficient for fixator removal when the bone was corticalized on three of four sides as seen on the anteroposterior and lateral xray films (12, 15).

Ten cases in this series were treated with a Sarmiento orthosis or a plaster of Paris cast for an additional two months (range one to three months), because of our fear of refracture. Review of the procedures indicates that that part of the treatment does not seem necessary on a routine basis.

At follow-up examination 42 months (range 24 to 61 months) after frame removal, the final outcome was evaluated. Residual leg length discrepancy was detected by the wooden board method (5, 11, 13, 14), and standard radiological examination was performed to reveal possible refractures and to measure angulations. Information about patient satisfaction was collected by means of a questionnaire filled in by the patient in advance.

RESULTS

Fifteen nonunions united (94%), and all infections were eradicated. Limb length discrepancy was reduced (when treated) to within 15 mm of the contralateral leg (average 8 mm) ; there were no residual angulations, malalignment or rotational deformities. Average time in frame was 182 days (range, 100 to 304 days). Bone formation regenerated by distraction osteogenesis in the distraction gap of osteotomies or nonunion sites or both, performed in 10 patients, averaged 49 mm (range, 6 to 90 mm). The average healing index was 62 days per cm.

Thirteen patients (81%) returned for follow-up. They were all satisfied with the treatment (table IV), and none of them had suffered refracture or recurrent infections.

Complications were subclassified according to Paley (17) in "problems" solved during treatment without operative intervention ; "obstacles" that required an operative intervention and true "complications" that were not resolved before the end of treatment. The true complications were considered minor if they did not interfere with achieving the original goal. We recorded 13 problems in 12 patients, seven obstacles in five patients and one minor and one major complication. The problems consisted of seven patients with pin-site inflammation, four patients with pin-site soft tissue infection and two patients with transient paresthesias. Obstacles were noted in two patients who developed neuromas or granulomas which were treated successfully by excision under local anesthesia. One patient with a hypertrophic nonunion experienced fatigue fracture of a wire twice during the distraction period owing to premature consolidation. The wires were replaced without negative consequences to the treatment. One patient had a lengthening procedure, but changed to an intramedullary nail for the consolidation period, because she could not endure the external fixator. Her second obstacle was a fatigue fracture in the nail, resolved by operative replacement. One patient did not react as expected to the "accordion maneuver", so a conventional cancellous autograft at the nonunion site was performed. The minor complication was recorded in a young female (case 2) who lost her anterior crural muscles, nerves and vessels from the primary injury. She had a lengthening procedure that exceeded the bone loss by 5 mm. This was done to overcome the equinus position of her foot following the muscle defect, but one year later a subtalar Lambrinudi arthrodesis was performed because of instability. The major complication was observed in a patient who suffered from fracture,

Table IV. — Patient characteristics at follow-up

No	FU time (months)	shortening (mm)	pain during treatment	pain now (rest)	pain now (work)	overall satisfaction
2	61	0	7	7	10	10
3	56	0	4	10	7	10
6	59	15	3	5	3	7
7	56	0	4	6	6	9
8	47	0	7	8	5	8
9	50	0	7	8	3	9
10	41	15	6	10	6	9
11	37	10	6	9	6	10
12	31	15	3	9	2	7
13	27	5	8	10	10	10
14	31	15	8	10	10	10
15	24	10	3	9	7	10
16	26	15	6	10	7	10
average :	42	8	6	9	6	9

Pain and satisfaction : 10 = no pain / very satisfied, 1 = unbearable pain / very bad.

nonunion and complications for fifteen years until he underwent Ilizarov treatment. During those years he sustained long periods of disability from severe pain. After six weeks "accordion maneuver" followed by six weeks of consolidation, xrays showed good signs of healing. Because of pain he demanded frame removal, and we agreed provided that he wore a Sarmiento orthosis for a further three months. Four days after frame removal he still had severe pain, and he requested a below-knee amputation.

A male patient, 15 years old at the initial operation (case 1) had a bone loss of 130 mm. He went through a lengthening procedure of 90 mm. (214 days in the frame). Because of his age, the expected remaining growth potential, and the long period of treatment he had already been through, the goal for the first Ilizarov treatment was to achieve union and eradicate infection. His soft tissues could then adjust to the new length, and he later returned for further lengthening.

DISCUSSION

Failures in the treatment of tibial nonunion are often followed by amputations. Following conventional treatment with bone grafting, plate and screw osteosynthesis, external fixation or prolonged cast immobilization, an amputation frequency of 10% is reported (6). By using the Ilizarov technique this frequency seems lower, but not all amputations can be avoided (3, 4, 16). Previous studies recommend early amputation in cases with type III-C injury (7). We report on 16 tibial nonunions of which one was finally amputated despite good signs of healing, but the other 15 had good results, including the two type III-C injuries. Especially when dealing with chronically infected bone or extensive bone loss, the treatment of tibial nonunion by the Ilizarov method is favorable. The use of bone transport technique has in most cases eliminated the need for free vascularized bone grafting to treat chronically infected tibial nonunion with bone loss, because the Ilizarov technique gives better results concerning bone healing, and because of the opportunity for correction of deformities and shortening at the same time (16). The aim of a successful Ilizarov treatment for nonunion is not just to achieve healing of the nonunion, it is also to achieve a leg without deformities, shortening or infection with a normal range of motion and normal strength of bone and soft tissues. The duration of treatment is long, but can usually be predicted before it is initiated, so the patient knows the long-term plan. The treatment is very demanding both to the surgeon and to the patient, but we strongly recommend the Ilizarov treatment for tibial nonunion especially in cases with chronic infection and severe bone loss.

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SAMENVATTING

M. B. LAURSEN, P. LASS, K. S. CHRISTENSEN. Ilizarov-behandeling van tibiale pseudo-artrose : 16 gevallen.

Bij 16 patiënten met complexe tibiale pseudo-artrose werd een Ilizarov-techniek gebruikt. Twee jaar na de behandeling werd de funtionele status en de patiënt's tevredenheid genoteerd.
Er waren 4 hypertrofische, 3 atrofische en 9 geïnfecteerde pseudo-artrosen. Bij 11 patiënten was er een segmentaire botverlies. 15 pseudo-artrosen consolideerden met een lengteverschil tot 1,5 cm van de contralaterale zijde. De gemiddelde tijd voor behandeling was 182 dagen ; 15 van de 16 patiënten waren tevreden over de behandeling ; 1 patiënt verzocht om een amputatie na 3 jaar behandeling ondanks goede tekens van heling. Er waren geen re-fracturen noch recurrente infecties.

RÉSUMÉ

M. B. LAURSEN, P. LASS, K. S. CHRISTENSEN. Traitement des pseudarthroses du tibia par la technique d'Ilizarov : résultat dans 16 cas..

Les auteurs ont utilisé la technique d'Ilizarov pour traiter 16 patients qui présentaient des pseudarthroses complexes du tibia. La récupération fonctionnelle et le degré de satisfaction du patient ont été notés deux ans après le traitement. Les cas traités comprenaient quatre pseudarthroses hypertrophiques, trois athrophiques et neuf infectées. Onze patients présentaient une perte de substance osseuses segmentaire. Quinze pseudarthroses ont consolidé, et la différence de longueur des membres inférieurs a été réduite à moins d'1,5 cm. Les patients ont porté l'appareil d'Ilizarov pendant 182 jours en moyenne. Quinze des 16 patients se sont déclarés satisfaits du traitement. Le dernier a réclamé une amputation après trois mois de traitement, malgré des signes de consolidation osseuses. Il n'y a pas eu de refracture ni d'infection récidivante.
En conclusion, la technique d'Ilizarov utilisée pour traiter des pseudarthroses complexes du tibia donne un taux de succès en ce qui concerne la consolidation osseuse, l'éradication de l'infection et la correction de la perte de substance osseuse et des défauts d'alignement. Le traitement est exigeant à la fois pour le chirurgien et pour le patient mais les auteurs recommendent ce traitement pour les pseudarthroses tibiales, en particulier avec infection chronique et perte osseuse importante.