Acute shortening and re-lengthening in the management of bone and soft-tissue loss in complicated fractures of the tibia

M. A. El-Rosasy

From the University
of Tanta, Tanta,
Egypt

We have managed 21 patients with a fracture of the tibia complicated by bone and soft-tissue loss as a result of an open fracture in 10, or following debridement of an infected nonunion in 11, by resection of all the devitalised tissues, acute limb shortening to close the defect, application of an external fixator and metaphyseal osteotomy for re-lengthening. The mean bone loss was 4.7 cm (3 to 11). The mean age of the patients was 28.8 years (12 to 54) and the mean follow-up was 34.8 months (24 to 75).

All the fractures united with a well-aligned limb. The mean duration of treatment for the ten grade-III A+B open fractures (according to the Gustilo-Anderson classification) was 5.7 months (4.5 to 8) and for the nonunions, 7.6 months (5.5 to 12.5). Complications included one refracture, one transient palsy of the peroneal nerve and one equinus contracture of 10°.

Defects of bone and soft-tissue in the leg may be the result of high-energy trauma or may follow surgical debridement for infection or tumour.¹⁻⁵ Traditional methods of obtaining soft-tissue cover followed by bone grafting are lengthy and the functional outcome may be unsatisfactory because of residual leg-length discrepancy, deformity, the psychological problems of prolonged treatment and repeated surgery. There is a risk of morbidity of the donor site and such procedures may not be applicable in the presence of infection.^{2,4,6}

The use of the Ilizarov² technique has improved limb reconstruction, but there are difficulties and complications, particularly during bone transport and at the docking site.^{1,2,7-10}

We present the results of acute limb shortening and re-lengthening using external fixation for bone and soft-tissue defects of the leg, with particular emphasis on the safe limits for limb shortening and the approaches used in this technique.

by bone and/or soft-tissue loss of more than 3 cm. Patients with peripheral vascular insufficiency, extensive soft-tissue scarring and induration from previous surgery, or long-lasting infection and hypertrophic nonunion of the tibia, were excluded from the study.

The time between the original injury and treatment varied between one week and three years.

The patients were divided into two groups depending on the time of referral. The first, or early treatment, group had been referred between one and six weeks after injury and had no attempts at bone or soft-tissue reconstruction. There were 10 patients in this group; seven fractures were grade IIIA and three grade IIIB according to the Gustilo and Anderson¹¹ classification of open fractures. The second group consisted of 11 patients with established atrophic nonunion of the tibia of more than six months duration with bone loss and limb shortening. They had all had previous attempts at soft-tissue cover and debridement for infection.

There was active infection at the time of presentation in ten of the 21 patients. One patient presented with nonunion of the distal tibia and an ankylosed ankle. Two had fractures of the distal tibia involving the articular surface complicated by infection, in whom the ankle was not salvageable.

■ M. A. El-Rosasy, MSc, MD,
Lecturer in Orthopaedic
Surgery
Department of Orthopaedic
Surgery and Traumatology,
Faculty of Medicine
University of Tanta,
Al-Geish Street, Tanta, Egypt.

Correspondence should be
sent to Dr M. A. El-Rosasy; e-
mail: elrosasy@yahoo.com

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Patients and Methods

Between 1997 and 2002, 21 patients were treated. All had been referred after prior management in local hospitals. Their mean age was 28.8 years (12 to 54). They had fractures of the shaft of the tibia or distal tibial fractures involving the ankle joint and were complicated

Table I. Clinical details of the 21 patients

Case	Gender	Age (yrs)	Side	Level of fracture*	Grade of fracture ¹¹	Skin condition	Infection status
Early treatment group							
1	M	40	L	M	IIIA	Open wound	Resolved
2	M	19	L	L	IIIA	Open wound	Resolved
3	M	13	R	L	IIIA	Open wound	Active
4	M	28	L	M	IIIA	Open wound	Resolved
5	M	22	L	L	IIIB	Open wound	Active
6	M	38	L	U	IIIA	Open wound	Active
7	F	45	L	L	IIIB	Open wound	Active
8	M	42	L	M	IIIA	Open wound	Resolved
9	M	12	R	M	IIIB	Open wound	Active
10	M	36	L	U	IIIA	Open wound	Resolved
Nonunion group							
11	M	23	L	M	Nonunion	Adherent scar	Resolved
12	M	17	L	U	Nonunion	Old STSG [†]	Resolved
13	F	41	L	Distal articular	Nonunion	Old STSG	Resolved
14	M	21	L	U	Nonunion	Adherent scar	Resolved
15	F	20	R	M	Nonunion	Sinus	Active
16	M	23	L	Distal articular	Nonunion	Sinus	Active
17	M	21	R	L	Nonunion	Old graft	Resolved
18	M	47	L	M	Nonunion	Sinus	Active
19	M	22	L	M	Nonunion	Sinus	Active
20	M	21	L	M	Nonunion	Adherent scar	Resolved
21	F	54	L	U	Nonunion	Adherent scar	Active

* M, middle third; L, lower third; U, upper third

† STSG, split-thickness skin graft

Table II. Details of the 21 patients in regard to bone loss, bone quality, previous treatment, fixation and comorbidity

Case	Bone loss (cm)	Bone quality	Previous treatment*	Retained hardware	Comorbidity
Early treatment group					
1	3.5 debridement	Good	POP cast		Smoking
2	3.0 debridement	Good	POP cast		
3	3.0 debridement	Good	POP cast		
4	4.0 debridement	Good	POP cast		Smoking
5	7.0 debridement	Good	POP cast		Smoking
6	3.0 debridement	Good	POP cast		Smoking
7	3.5 debridement	Good	POP cast		Morbid obesity
8	4.0 infection	Good	POP cast		Smoking
9	4.0 debridement	Good	POP cast		
10	3.0 debridement	Good	POP cast		Smoking
Nonunion group					
11	3.0 debridement	Good	POP cast		
12	5.0 (3 infection + 2 debridement)	Porous	IM nail	IM nail	Smoking
13	8.0 traumatic	Porous	POP cast		Morbid obesity
14	11.0 (8 traumatic + 3 debridement)	Porous	POP cast		Smoking
15	3.0 infection	Good	POP cast		
16	5.0 infection	Porous	Plate and screws and multiple Kirschner wire	Plate and screws	Smoking
17	7.0 infection	Porous	POP cast		Smoking
18	6.0 infection	Porous	IM nail and plate and screws	Plate and screws	Smoking
19	6.0 debridement	Porous	Plate and screws		Smoking
20	4.0 debridement	Porous	External fixator		
21	3.0 debridement	Porous	POP cast		Morbid obesity and diabetes mellitus

* POP, plaster of Paris; IM, intramedullary

The remaining 18 patients had mobile ankles at the time of treatment.

The mean total bone loss, as a result of the original injury and/or surgical debridement was 4.7 cm (3 to 11).

All patients were operated on and followed up by the author (MAE), at the author's institute. Tables I and II give the clinical details of the patients.

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Photographs of the Z-incision shortening technique showing a) the outline of the incision centred on the site of nonunion, b) wide exposure of the nonunion, c) acute shortening and transposition of the limbs of the incision and d) good healing of the skin stretched during lengthening.

The five aims of treatment were to achieve union, soft-tissue healing, eradication of infection, restoration of leg length and restoration of function.

The circulation distal to the fracture was assessed by palpation of the dorsalis pedis and posterior tibial pulses and by Doppler ultrasound.

The pulse volume was compared with that of the healthy side. The skin was examined for the presence of sinuses, previous surgical incisions and skin grafts.

Debridement of all infected tissues and removal of retained hardware was carried out under tourniquet control. The tourniquet was then removed and haemostasis obtained.

Soft-tissue management. This depended on the aetiology of the defect. Traumatic skin loss was treated by planning the acute shortening so that the defect was closed acutely after shortening based on the level of the fracture and the size of the defect. In patients who presented late with a surgically-induced skin defect, appropriate skin incisions were used to facilitate closure after shortening. When the

required shortening was less than 5 cm, a transverse incision centred on the site of the nonunion was used. If the required shortening was > 5 cm, or in the presence of unhealthy skin, a Z-shaped incision was made. The horizontal limb of this incision was elliptical to allow excision of infected skin sinuses or the major part of a previous skin graft. During closure, the limbs of the Z-shaped incision were either replaced or transposed to increase the width at the expense of length in order to allow more shortening and to facilitate closure (Fig. 1). Longitudinal skin incisions were avoided in all cases.

In all patients the infected soft tissue, sinuses and unhealthy skin were excised and replaced by healthy tissues.

Management of the bone defect. The decision on the amount of resection required was taken intra-operatively and the bone divided at the limits of apparently healthy bleeding bone. Stability of the fracture was obtained by wedging one bone end into the other or by a square osteotomy of the bone ends in order to obtain the widest area of contact.

The fibula was treated by resection of the exposed bone. The resection was not necessarily equal to that of the tibia. In nine patients the fibula was intact and was osteotomised after debridement of the tibial fracture. The fibula was approached through the tibial defect and no separate skin incisions were necessary. The fibular osteotomy was done as far as possible from the tibial fracture with minimal muscle dissection to preserve an intervening muscle barrier. During limb shortening the bone ends of the fibula were overlapped and subsequently distracted during lengthening.

Fixation. An external fixator was then applied, the choice of which depended on several factors. An Ilizarov fixator (Smith & Nephew Inc., Memphis, Tennessee) was used when dealing with osteoporotic bone, limb lengthening of more than 5 cm and when fixation of the foot was necessary. A monolateral external fixator (Orthofix Srl., Verona, Italy) was preferred when the bone quality was good and limb lengthening relatively short (3 cm to 5 cm).

In four patients, a transcaneal Rush pin (Misr medical, Cairo, Egypt) was inserted from distal to proximal through a small incision in the heel. In the first two patients tibiotalar fusion was planned. In the third the ankle was stiff with a short distal tibial segment and in the fourth the planned acute shortening was 6 cm. The Rush pin was used to augment fixation of the osteoporotic bone and to avoid deflection of the bone ends during acute shortening. It was left as a permanent splint in the first three patients. In the fourth it was removed under local anaesthesia to allow movement of the ankle and full weight-bearing after completion of lengthening when soft-tissue tension had been regained.

Limb shortening. Acute limbshortening was obtained by compression with the external fixator. The amount of acute shortening was kept within safe limits which allowed a good distal blood flow. The distal circulation was checked

Table III. Evaluation of the results (modified from Paley et al¹)

Parameter	Satisfactory	Unsatisfactory
Bony union	United	Non-united
Residual deformity	Less than 5°	More than 5°
Residual leg-length discrepancy	Less than 2.5 cm	More than 2.5 cm
Recurrent infection	No more infection	Bone and/or soft-tissue infection
Soft-tissue healing	No exposed bone	Soft-tissue defect remaining
Permanent joint contracture	Less than 5°	More than 5°
Persistent pain	No or mild pain	Moderate or incapacitating pain
Return to previous work	Yes	Has to change job
Patient satisfaction	Satisfied	Not satisfied

throughout the operation by Doppler ultrasonography (Fukuda Denshi Co. Ltd, Bunjyo-Ku, Japan), palpation of the dorsalis pedis and posterior tibial arteries and capillary refilling as compared with the healthy side. If the distal blood flow was compromised, compression was released to allow it to return. When the bone defect was greater than the safe limit for acute limb shortening, the limb was shortened to the safe limit and the remaining gap gradually closed at a rate of 2 mm to 3 mm per day.

Limb lengthening. A lengthening osteotomy was carried out in the metaphysis farthest from the site of the fracture. Distraction of the lengthening osteotomy was started on the seventh post-operative day at an initial rate of 1 mm per day. Equalisation of leg length was checked both clinically and radiologically. For the patients with stiff ankles or a tibiotalar fusion, the affected limb was left 1 cm to 2 cm shorter than the normal side to allow for foot clearance during walking and the use of modified shoes.¹²

Bone grafting. Autogenous iliac crest bone graft was used at the time of the first operation in patients with long-standing atrophic nonunion if adequate bone-to-bone contact could not be obtained except with a large amount of additional bone resection. The bone graft was obtained in the form of cancellous bone chips from the iliac crest. In patients in whom the fracture had failed to unite after compression for three months, autogenous iliac crest bone grafting was performed with the fixation device in place. When grafting was done in this manner as a secondary procedure, great care was taken to avoid contamination of the operative site from the pin sites.

Follow-up. Patients were followed up every two weeks during lengthening and then every month until bone consolidation. The limb was assessed for problems at the pin site, neurovascular compromise and the progress of lengthening. They were then followed up at three months and subsequently annually for a minimum of two years. The mean follow-up was 34.8 months (24 to 75).

Weight-bearing was not started immediately after operation to avoid the development of soft-tissue oedema and late vascular compromise. The leg was kept elevated. Weight-bearing, as tolerated, was started two to three weeks post-operatively when the soft tissues had begun to stretch during distraction.

When the fracture was judged to be united radiologically, the fixation device was loosened and union was tested clinically.

Dynamisation was then begun to hasten bone consolidation.

Staged extraction of the pins was started after consolidation was established and the fixation device removed as an outpatient procedure without anaesthesia. A plaster cast was applied for one month and full weight-bearing allowed.

Evaluation. The results were assessed using the system described by Paley et al¹ with modification. This included evaluation of bony union, residual deformity, residual leg-length discrepancy, recurrent infection, soft-tissue healing, permanent joint contracture, persistent pain, return to previous work and patient satisfaction (Table III). The final results were considered to be satisfactory or unsatisfactory based on these findings.

Results (Tables IV and V)

Soft tissues. Primary wound closure was possible in 20 patients without the need for skin grafting. In one patient (case 9) acute shortening resulted in coverage of the exposed bone, tendons and neurovascular bundle by the redundant muscle belly. The exposed muscle was then covered by a split thickness skin graft.

One patient had a recurrent sinus over the anterior tibia despite union of the fracture and absence of deep infection. He smoked two packs of cigarettes per day and did not stop smoking during treatment. He required a rotational fasciocutaneous flap to cover the area.

Bone. Autogenous iliac crest bone graft was applied at the first operation in eight patients. Seven had atrophic nonunion and one in the early treatment group had inadequate bone contact because of hemicortical bone loss.

Secondary bone grafting was needed in two patients. One (case 12) developed a refracture at the site of the previous nonunion and required re-application of a monolateral external fixator and a bone graft. In case 17 the nonunion failed to show signs of healing after three months of compression-distraction. A bone graft was then applied with the device in place, followed by compression of the nonunion. Both united and have remained so at the latest follow-up.

The fractures united without the need for bone grafting in 12 patients, nine of whom were in the early treatment group.

Table IV. Results of treatment in the 21 patients

Case	Acute shortening (cm)	Bone graft*	Fixation method	Limb lengthening (cm)	External fixation time (mths)	External fixation index (mths/cm)	Total treatment time (mths)
Early treatment group							
1	3.5	X	Monolateral	3.5	4.8	1.4	6.0
2	3.0	X	Monolateral	3.0	4.0	1.3	5.0
3	3.0	X	Monolateral	3.0	3.5	1.1	5.0
4	4.0	X	Monolateral	4.0	5.0	1.2	6.0
5	6.0	X	Ilizarov	4.0	6.0	1.5	8.0
6	3.0	X	Monolateral	3.0	4.5	1.5	6.0
7	3.0	ICBG	Monolateral	3.0	4.6	1.5	5.5
8	4.0	X	Monolateral	4.0	5.2	1.3	6.0
9	4.0	X	Monolateral	4.0	4.3	1.0	5.0
10	3.0	X	Monolateral	3.0	3.5	1.1	4.5
Mean	3.6			3.4	4.5	1.2	5.7
Nonunion group							
11	3.0	ICBG	Ilizarov	3.0	4.5	1.5	5.5
12	4.0	ICBG	Ilizarov	4.0	4.8	1.2	8.6
13	4.0	X	Ilizarov + Rush pin	4.0	5.2	1.3	6.0
14	3.0	ICBG	Ilizarov	7.0	8.7	1.2	10.0
15	3.0	X	Monolateral	3.0	4.6	1.5	5.7
16	5.0	ICBG	Ilizarov + Rush pin	4.0	5.1	1.2	6.5
17	6.0	X	Ilizarov + Rush pin	9.5	11.6	1.2	12.5
18	4.0	ICBG	Monolateral	4.5	6.4	1.4	7.5
19	6.0	X	Ilizarov + Rush pin	6.0	7.2	1.2	8.5
20	3.0	ICBG	Ilizarov	6.0	7.3	1.2	8.0
21	3.0	ICBG	Monolateral	3.0	4.3	1.4	5.5
Mean	4.0			4.9	6.3	1.3	7.6

* X, no bone graft used; ICBG, iliac crest bone graft

Table V. Details of complications, residual leg-length discrepancy, secondary procedures and follow-up in the 21 patients

Case	Complications*	Residual leg-length discrepancy (cm)	Secondary procedures†	Follow-up (mths)
Early treatment group				
1	X	X	X	30
2	X	X	X	31
3	X	X	X	31
4	X	X	X	31
5	Knee flexion contracture 15° SPTI	3	X	75
6	X	X	X	26
7	SPTI	X	X	24
8	X	X	X	38
9	X	X	STSG	30
10	X	X	X	36
Mean				35
Nonunion group				
11	X	X	X	48
12	Re-fracture peroneal nerve palsy	3	Re-application of external fixation Monolateral + ICBG	42
13	SPTI	4	Frame re-adjustment	38
14	X	4	X	33
15	X	X	X	36
16	Knee flexion contracture 15°	1	X	33
17	Knee flexion contracture 20°	1	ICBG	24
18	Skin sinus	1.5	Rotational flap	41
19	X	X	X	25
20	SPTI/equinus contracture 10°	1.5	X	26
21	SPTI	X	X	33
Mean				34.4

* X, none; SPTI, superficial pin-track infection

† STSG, split thickness skin graft; ICBG, iliac crest bone graft

Fibular osteotomy was performed in nine patients through the tibial defect and intermuscular planes. There were no instances of tibiofibular synostosis.

Acute shortening. The safe limits for acute leg-shortening were estimated, at different levels of fractures, based on the operative and follow-up observations. These values were verified both clinically and by Doppler ultrasound. Trials to exceed these limits were hampered either by vascular compromise or tissue buckling, which did not allow more acute shortening. Based on these results, the relatively safe limits for acute shortening were estimated as: upper third of the leg, 3 cm (5 cases; 24%); middle third 3 cm to 5 cm (9; 43%); lower third, < 6 cm (7; 33%). In eight cases (38%), the bone defect was greater than the safe limit for acute leg-shortening at the specified level of fracture; in these cases, acute shortening was carried out to the safe limit and the remaining gap was gradually closed post-operatively at a rate of 2 mm to 3 mm per day.

Method of fixation. A total of 22 fixators were applied during the study. An Ilizarov fixator was used in nine cases (43%) and a monolateral fixator in 13 (59%). In the early treatment group, a monolateral fixator was used in nine patients and an Ilizarov fixator in only one. In the nonunion group a monolateral fixator was used in three patients and an Ilizarov fixator in eight. One patient in this group (case 12) had a monolateral fixator applied as a secondary procedure.

Limb lengthening. Concomitant leg lengthening was undertaken in all patients with a mean of 4.2 cm (3 to 9.5). Equalisation of leg length was achieved in 13 patients. Leg-length discrepancy of 1 cm to 1.5 cm occurred in four patients who had stiff or fused ankles. Another four patients had a residual discrepancy of 3 cm to 4 cm. The reasons for cessation of limb lengthening were the development of a flexion contracture of the knee, recurrent pin-track infection and intolerance of the procedure. One case of leg-length discrepancy > 3 cm occurred in the early treatment group and the remaining three were in the nonunion group.

Joint stiffness. Flexion contracture of the knee of 15° to 20° developed in three patients and was managed by physiotherapy during treatment and after removal of the fixator. No patient had a residual flexion contracture of the knee. Equinus contracture of the ankle of 10° occurred in one patient during distal tibial lengthening of 6 cm. No permanent joint stiffness occurred in any patient as a result of this treatment. In the patient in whom the Rush pin was extracted, there was temporary stiffness of the ankle, but after removal of the pin a full range of movement was regained by physiotherapy.

Complications. Recurrent superficial pin-track infection occurred in five patients and was treated by local care and oral antibiotics. In one patient the infected pins were replaced and the frame adjusted. No patient developed a deep infection.

One patient (case 12) with atrophic nonunion in the upper third of the tibia developed a transient peroneal nerve palsy after acute shortening of 4 cm. The amount of shortening was reduced, followed by gradual compression a few days later; the palsy resolved completely.

In the same patient, when the nonunion was judged to be united clinically and radiologically, the fixator was removed and a plaster-of-Paris cast applied for one month. Two weeks after removal of the cast the patient presented with a re-fracture at the original site of the nonunion. This was treated by iliac crest bone grafting and a monolateral fixator. The nonunion healed after four months and remained united at the latest follow-up.

No cases of recurrent infection or osteomyelitis were encountered during follow-up. There were no cases of permanent nerve injury or vascular compromise.

Outcome of treatment. The duration of external fixation and the external fixation index were greater in the nonunion group than in the early treatment group. Most of the problems associated with treatment, complications and secondary procedures occurred in the nonunion group (Tables IV and V).

Based on the parameters in Table III, the results were considered satisfactory in 17 cases and unsatisfactory in four, due to residual leg shortening of > 2.5 cm. Figure 2 shows an example of the treatment.

Discussion

The treatment of tibial fractures complicated by bone and soft-tissue loss remains a considerable challenge. Many methods of treatment have been described with varying degrees of success.^{2,3,5-7,13-16}

The Ilizarov technique of compression-distraction histogenesis has revolutionised the treatment of these patients. The original treatment included radical resection of the pathological tissues followed by corticotomy in the metaphysis farthest from the operative site for bone and soft-tissue transport.¹⁴ With the increased use of transport for bridging bone defects, several difficulties and complications have emerged. Most of these problems are related to the process of transport and of bringing the bone ends into contact at the docking site.^{2,7-10}

Acute limb shortening and relengthening has been described for the management of longitudinal bone defects with or without soft-tissue loss due to different aetiologies.^{5,12,15-18} It can be considered as the advancement of a large vascularised osteocutaneous flap to close the defect, thus replacing all devitalised and infected tissues by local healthy tissue without the need for grafting in most cases.

Saleh and Rees¹⁵ compared the results of the treatment of bone defects by bone transport with those of acute limb shortening followed by lengthening. They obtained excellent results in 12 patients (75%) and good results in four (25%). They found a shorter treatment time and fewer complications with the limb shortening and relengthening method. They recommended that acute shortening should

Fig. 2a

Fig. 2b

Fig. 2c

Fig. 2d

Fig. 2e

Fig. 2f

A 24-year-old man with atrophic nonunion after a grade-IIIB open fracture of the tibia. Figures 2a and 2b - Pre-operative anteroposterior (AP) and lateral radiographs showing bone loss of 5 cm and total shortening of 7 cm. Figures 2c and 2d - Post-operative AP and lateral radiographs showing application of the Ilizarov external fixator, the Rush pin, closure of the defect and the proximal osteotomy. Figures 2e and 2f - Follow-up AP and lateral radiographs show consolidation of the nonunion, lengthening of 9.5 cm and good alignment of the bone.

be considered for tibial defects of ≤ 3 cm and femoral defects of ≤ 5 cm.

Sen et al¹⁷ described the results of acute shortening and re-lengthening in the acute treatment of grade-III open tib-

ial fractures with osteocutaneous loss in 24 patients. Using the evaluation system of Paley et al,¹ the bone results in their series were excellent in 21 and good in three. The functional result was excellent in 19, good in four and fair in one patient. No bone or skin grafts were used.

In this series of 21 patients, ten were treated shortly after injury and 11 after they had developed nonunion. Both groups received similar treatment. Satisfactory results were obtained in both groups but, mainly due to residual leg-length discrepancy in the nonunion group, the functional results were better in the early treatment group.

Paley et al¹ had similar findings and explained that the ability to achieve an excellent bone result did not guarantee a good functional result, which was predetermined by the condition of the soft tissues and joints.

It has been recommended that the safe limit for acute leg shortening is 3 cm and a greater defect should be closed gradually to avoid neurovascular compromise.^{15,17}

Mahaluxmivala et al¹⁸ reported 18 patients who had nonunion of their tibial fracture, with excellent radiological results. In six cases they performed acute limb shortening and re-lengthening, and they were able to shorten the leg acutely up to 6 cm, but they did not indicate the level of shortening in the tibia (i.e. upper, middle or distal third).

In this study, acute limb shortening of up to 6 cm was achieved. However, no absolutely safe limits for acute shortening can be suggested and every case should be monitored intra-operatively. Post-operative monitoring is mandatory because soft-tissue oedema can result in late neurovascular compromise, in which case the shortening should be relieved.

The suggested limits for limb shortening should be considered during pre-operative planning. For a bone defect of 3 cm, a transverse skin incision would be adequate, but a Z-shaped incision should be used for a defect of 5 cm. There are specific problems in peri-articular bone defects. Defects in the upper third may not be closed immediately because of vascular problems. In the vicinity of the ankle, overzealous shortening may cause the skin to buckle with subsequent ischaemia leading to skin loss which is difficult to manage in this location.

Simpson, Andrews and Giele¹⁹ described the Z-incision technique to facilitate acute shortening, better skin closure and excision of unhealthy skin. In the current series similar incisions were used and were found to be very helpful. During limb lengthening the soft tissue stretched out and regained its tension. The Z-shaped incision allowed wide exposure of the site of nonunion, and fibular osteotomy could be performed without the creation of a new incision.

Paley et al¹ have discussed the importance of obtaining bone contact for greater stability of the construct and described several methods for obtaining this by open or closed means. They reported better results in terms of union and eradication of infection following debridement at the site of nonunion.

Acute shortening results in an inherently stable pattern of the fracture. Having immediate stability allows the patient to walk and bear weight soon after surgery. In acute cases this active and functional management can shorten the time of treatment and reduce costs and absence from work.

Acute limb shortening should result in a well-aligned and straight, but short, leg with adequately matched and compressed bone ends. The next step is the choice of the fixator to be used for stabilisation and linear lengthening. In this study a monolateral external fixator was used for short-segment lengthening of less than 5 cm, with good bone quality. The Ilizarov external fixator was reserved for patients with osteoporotic bone, lengthening of more than 5 cm and when foot fixation was required. The use of a monolateral fixator simplified the fixation and was tolerated better by the patients.

Compared with the early treatment group, a longer treatment time with more complications and need for secondary procedures were encountered in the nonunion group. Similarly, the need for bone grafting was greater in this group. Bone grafting in the early treatment group was needed only once because of inadequate bone contact.

Due to the small number of cases, statistical analysis could not be performed to compare the functional results between the two groups of patients.

Despite being simpler than bone transport, careful attention to the technical detail is needed. The procedure should be carefully explained to the patients because their co-operation, and the psychological and social support of their care-givers are necessary throughout this painstaking procedure.

Acute limb shortening and re-lengthening is another powerful technique for bridging soft tissue and bone defects and restoration of limb function in one procedure without the need for further reconstructive procedures in most cases. Although based on the Ilizarov techniques, it eliminates the problems frequently encountered with bone transport by converting a complicated limb reconstruction into a relatively simpler one of linear limb lengthening. It is recommended to be used as definitive treatment immediately after trauma, and not to be considered as a salvage procedure, to ensure the best functional results.

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