

# Limb lengthening by callus distraction

## Complications in 53 cases operated 1980-1991

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We reviewed our first 53 lengthenings performed in 45 patients with an average age of 19 years at the time of lengthening. The shortening was congenital in 16 patients, post-traumatic in 15 and had various causes in the 14 remaining. 31 femurs and 22 tibiae with an average shortening of 6 and 5 cm, respectively, were lengthened 6 (2-14) cm. The aim was achieved in all but 4 patients, where lengthening had to be discontinued due to complications.

Potential complications of lengthening can be numerous but, if recognized, can in most cases be dealt with during the extended lengthening procedure.

38 cases of pin-tract infections healed with antibiotics. Restricted motion in one or more joints was registered in 49 cases during lengthening; minor restriction of joint motion persisted in 14 patients. 28 cases had angular deviations during lengthening. After additional surgery all but 10 could be corrected. 4 fractures occurred after removal of the external fixator. The total number of complications was 146, and of these 76 were minor, 42 moderate and 28 severe. 36 of the 42 patients available to follow-up were satisfied with the results of the lengthening procedure.

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The initial reports on callus distraction (Monticelli and Spinelli 1983, De Bastiani et al. 1987, Ilizarov 1988, Paley 1988, Aldegheri et al. 1989) had a low rate of complications; this is in contrast to what most surgeons now experience (Paley 1990, Eldridge and Bell 1991).

Our first 53 callus distraction lengthenings performed in 45 patients were retrospectively assessed with regard to the complication rate and the long-term results.

### Patients and methods

53 limb lengthenings (LLs) were performed with callus distraction in 45 patients at our department between April 1980 and January 1991: there were 25 female and 20 male patients, with an average age of 19 (5-43) years (Table 1).

5 patients had previously undergone one or more lengthenings with the Wagner (1972) technique. 6 patients had been subjected to epiphysiodesis or shortening operations in an effort to eliminate limb length inequality (LLI) and 8 to corrective osteotomies due to malalignment of the short limb. 3 patients had undergone tendon lengthening and 2 corrective foot surgery. 2 patients, with a considerable equinus, underwent corrective foot surgery

immediately prior to the LL with external fixators (EFs) which were retained for lengthening purposes.

Prior to LL, a restricted degree of joint motion was present in 3 hips, 12 knees and 8 ankles of the short leg. 2 knees and 1 ankle were ankylosed.

The shortening was congenital in 16 patients, post-traumatic in 15 and had various causes in 14. Right and left legs were equally represented. LLI was determined with an orthoradiographic technique. 27 femurs had an average shortening of 7 (2-14) cm and 18 tibiae 6 (3-11) cm.

The 2 patients of short stature (120 cm and 144 cm) underwent bilateral femoral and tibial lengthenings. 2 patients with a congenital shortening of 1 leg were each subjected to 2 lengthenings.

42 patients were clinically examined with regard to range of motion (ROM) in hip, knee and ankle joints and were radiographically assessed (orthoradiographs, lateral views of the lengthened segment and long AP views of the lower extremities) at an average follow-up of 4 (1-11) years. These patients also completed a questionnaire in which they were asked to state whether they were satisfied, dissatisfied or undecided about the result of the lengthening.

The medical reports of 2 patients, who were lost to follow-up, included a physical examination as regards ROM performed 5 years after the lengthening. 1 patient, in whom lengthening was terminated

prematurely, was excluded with regard to the long-term results.

### Technique

39 of the lengthening operations were performed under general anesthesia and 14 with epidural analgesia, with the patients in a supine position. The position of the bone-screws/K-wires was verified with image intensification.

6 Hoffmann, 22 Orthofix and 3 Ilizarov EFs were employed in the 31 femoral LLs. The corticotomy was performed via a lateral incision and, after drilling of the cortex, the bone was divided with a chisel (De Bastiani et al. 1987): 26 of these were proximal femur, while 5 were distal because of malalignment.

5 Hoffmann, 8 Orthofix, 6 Ilizarov and 3 Monticelli-Spinelli EFs were employed in the 22 tibial LLs. The distal tibiofibular syndesmosis was secured with a screw or, if a circular EF was used, with a K-wire, before the fibula was osteotomized. The tibia was corticotomized via a ventral incision with a chisel after drilling. 21 corticotomies were proximal and 1 distal. All corticotomies were unifocal. In the bilateral cases, simultaneous unilateral femoral and tibial lengthenings were carried out. 2 surgeons performed or attended all lengthenings.

Mobilization commenced on the first postoperative day and the patients were encouraged to partial weight bearing. Distraction was delayed for 7 days (White and Kenwright 1990), and then carried out at a rate of 1 mm per day, in 4 increments. The distraction rate was reduced or temporarily stopped if the patients experienced severe pain or developed contractures.

The patients were clinically and radiographically assessed, on an out-patient basis, every second to third week during the lengthening procedure and once a month during the consolidation period.

The EFs were removed under general anesthesia in all but 2 cases, when the regenerated bone displayed an even density and a neo-cortex on plain radiographs (Young et al. 1990, Walker et al. 1991). All but 5 lengthenings were left without external support, but the patients were ordered partial weight bearing with crutches for 1 month, after the removal of the EF. In 5 tibial lengthenings the leg was protected with a short walking cast for one additional month.

## Results

The mean operation time was 95 (40-230) min. The mounting of the circular frames (Ilizarov and Monti-

celli-Spinelli) averaged 140 (80-230) minutes, compared with 80 (40-135) min for the unilateral EF (Orthofix). The average peroperative blood loss was 150 (0-600) mL and no blood transfusions were required. Postoperative pain necessitated morphine administration in 31 of the lengthenings.

The time spent in hospital subsequent to primary surgery averaged 12 (4-78) days and the total time spent in our department during the LL was 25 (5-111) days. The bilateral LLs spent an average of 96 (66-111) days per lengthened side in hospital.

The mean femoral lengthening was 6 (2-14) cm and the tibial 6 (3-10) cm. All but 8 cases had a remaining LLI of less than 1 cm. The therapeutic aim in 4 of these was set at a discrepancy of a maximum of 2.5 cm due to preoperatively stiff joints and/or foot problems. In the remaining four cases, 3 femurs and 1 tibia, complications necessitated the termination of LL, with a remaining LLI of 2, 3, 6, and 10 cm, respectively.

In the 2 bilateral cases, the lengthening aims were set at 10 and 20 cm and the lengths achieved were 11 and 19 cm, respectively.

The EFs were removed after 221 (90-420) days. The healing index, i.e., the number of days from corticotomy to the removal of the EF per lengthened cm, was 39 (23-75). In 14 cases the index was 30 or less and in 16 it exceeded 40. The femurs had an average index of 36 and the tibias 40. In patients younger than 20 years of age the index was 32 for the femurs and 44 for the tibias.

At follow-up, 14 patients displayed restricted joint motion when compared with their preoperative status. The impairment, which was never in excess of 30°, affected 1 hip and 8 knees after femoral lengthening and 2 knees and 5 ankles after tibial lengthening.

36 patients were satisfied with the results of the lengthening, 3 were dissatisfied, and 3 were undecided about whether they had benefited from surgery or not. The 3 patients were dissatisfied due to a subjective cosmetic deterioration combined with a slightly impaired knee flexion in the second case and more problems from a primarily ankylotic ankle joint in the third. The undecided patients specified a remaining LLI, cosmetic reasons and/or minor restriction of knee flexion as the prime cause of their indecision about the result.

### Complications

The average number of anesthetics performed per lengthening was 3.4 (1-8). Without complications 2 surgical interventions could be expected, i.e., the lengthening operation and removal of the EF. 36 LLs

Table 2. Operations in 53 lengthenings

Patients	Additional anesthetics (excess of 2)	Operations performed	n
15	1	Angular and/or fixator correction	11
		Recorticotomy	2
		Achilles tendon lengthening	2
		Tendon lengthening	1
		Minor surgery	1
12	2	Angular and/or fixator correction	15
		Recorticotomy	2
		Achilles tendon lengthening	2
		Internal fixation	1
		Bonegrafting	1
		External fixation foot	1
4	3	Angular and/or fixator correction	8
		Achilles tendon lengthening	2
		Tendon lengthening	1
		Bonegrafting	1
3	4	Angular and/or fixator correction	5
		Achilles tendon lengthening	2
		Bonegrafting	1
		Neurolysis	1
1	5	Minor surgery	3
1	6	Angular and/or fixator correction	5
1	6	Angular and/or fixator correction	3
		Tendon lengthening	2
		Minor surgery	1

2 patients required only 1 anesthesia, i.e., the external fixator could be removed without any analgesia. 15 lengthenings necessitated 2 anesthetics, while additional anesthetics were required in 36 cases. More than one surgical procedure could be performed during the same anesthesia. The total number of operations, including primary surgery and removal of the EF, was 180.

required more than 2 anesthetics (Table 2).

In one patient with a LLI of 12 cm, femoral lengthening was discontinued after 2 cm due to a psychotic reaction and the bone was stabilized internally.

### Infections

Pin-tract infections were diagnosed in 38 cases. If redness, suppuration and/or local pain were observed around one or more of the pins, this was regarded as a sign of infection and peroral antibiotics were prescribed. No pin or screw had to be removed because of infectious complications and no deep infection or osteomyelitis was registered (Table 3).

### Neurovascular

5 patients, all of whom underwent tibial lengthening, suffered neurological impairment. In 2 of these the neurological deficit resolved after additional surgery and the lengthening procedure continued. In one, the peroneal nerve was impinged between a K-wire and the fibula; the K-wire was removed. The other had a

Table 3. Complications in 53 lengthenings. Recurrent pin-tract infections in 1 segment accounts for 1 complication

	Total number	Minor	Moderate	Severe
Pin-tract infection	38	38		
Neurological	5	3	2	
Vascular	0			
Restricted joint motion	49	30	5	14
Pes equinus	11	1	10	
Subluxation	2	1	1	
Angular deviation	28	1	17	10
Premature closure	6	1	4	1
Delayed union	3		3	
Fracture	4	1		3

Minor complications resolved without surgery. Moderate complications were surgically corrected. Severe complications persisted at the completion of the lengthening.

tarsal tunnel syndrome when the foot was dorsiflexed subsequent to Achilles tendon lengthening after 5 cm of lengthening. A tarsal tunnel release was performed. 3 patients complained of sensory impairment in the area innervated by the deep peroneal nerve. Sensory restitution occurred slowly when the EF was removed after the intended lengthening had been achieved. No vascular injury was noted.

### Joints

49 cases experienced a deterioration in joint motion during lengthening. Patients undergoing femoral lengthening exhibited restricted knee flexion and/or flexion contractures affecting the hip and knee joints. During tibial lengthening, contractures of the knee and foot were encountered. A temporary decrease in or discontinuation of the distraction rate and intensive physiotherapy usually reduced the contractures; in 3 cases surgical lengthening of the rectus femoris and sartorius were required. 11 tibial lengthenings developed significant equinus, 9 of which necessitated Achilles tendon lengthening. In 4 cases, a plantargrade positioning of the foot was established preoperatively or during lengthening with an EF.

3 patients with restricted knee motion subsequent to the lengthening underwent quadriceps release, which restored the ROM to its preoperative status in 2. One patient with a post-traumatic shortening and with fractures affecting the articular surface of the knee joint underwent a knee arthrodesis because of pain and severely impaired ROM after the LL. One patient with an absent fibula was operated with an ankle arthrodesis because of ankle instability.

At follow-up, 14 patients displayed restricted joint motion compared to their preoperative status.

2 subluxations, 1 of the hip after 14 cm of lengthening and 1 of the knee after 4 cm, were registered.

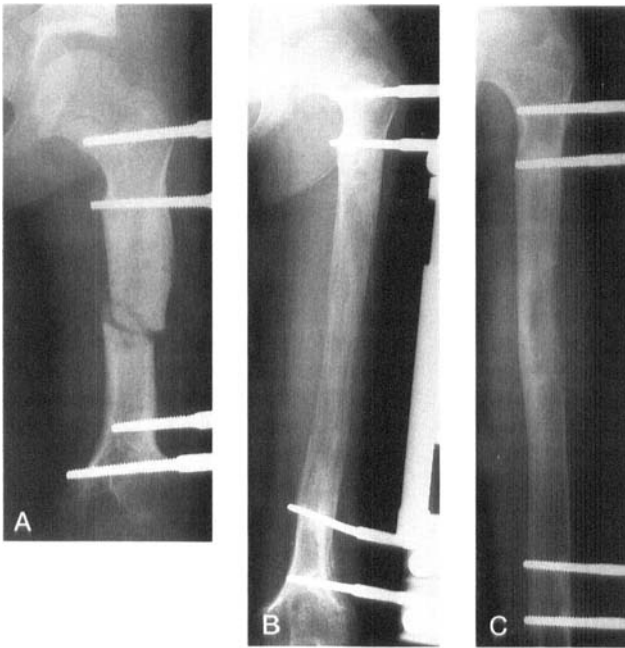


Figure 1. Case 36. 6-year-old boy with a LLI of 13.5 cm caused by osteomyelitis. The growth plates were closed, thus preventing further growth.  
 A. Start of lengthening.  
 B. Subluxation of the hip after 14 cm of lengthening. Lengthening was terminated and adductor tenotomy and lengthening of the rectus femoris and sartorius performed. The hip joint normalized.  
 C. At 11 years of age, a new femoral lengthening of 7 cm was performed without any complications in the hip joint.

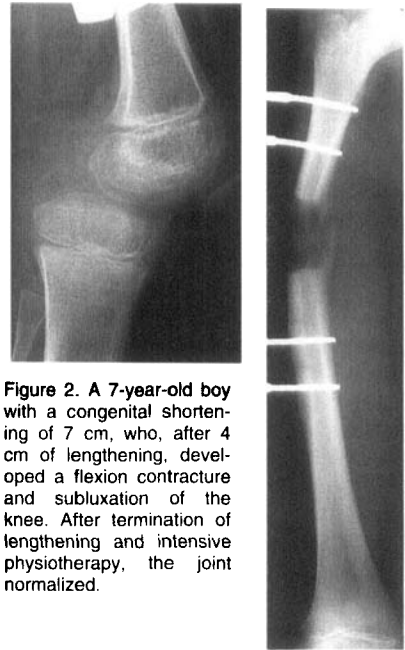


Figure 2. A 7-year-old boy with a congenital shortening of 7 cm, who, after 4 cm of lengthening, developed a flexion contracture and subluxation of the knee. After termination of lengthening and intensive physiotherapy, the joint normalized.

Figure 3. 8-year-old boy with congenital femoral shortening and progressive varus deviation during lengthening.

In both cases, the femoral lengthening was aborted. The knee function normalized after physiotherapy. The flexion contracture of the hip joint was surgically addressed and the joint positioned in an abduction splint. Both these joints recovered completely (Figures 1 and 2).

1 patient, who had undergone a femoral lengthening at the age of 7, displayed a dysplastic hip joint 9 years later, which necessitated a Salter osteotomy. The initial radiographs did not reveal any pathological findings in the hip joint and no complications occurred in the hip joint during lengthening. There was no radiographic evidence of joint injury caused by the lengthening procedure in any other patient.

### Skeletal

A premature consolidation of the corticotomy was registered in 3 femoral and 3 tibial lengthenings. Open re-corticotomy was performed in 3 patients, a closed re-corticotomy under general anesthesia in 1 and forced distraction in 1. Lengthening could in these cases be completed to the desired length.

Angular deviations exceeding  $10^\circ$  were registered in 18 of the 31 femoral lengthenings; 9 varus, 9 dor-

sal and/or 3 ventral, and in 10 of the 22 tibial lengthenings; 9 valgus and 1 dorsal (Figure 3). Angular corrections under anesthesia were performed 35 times in 23 cases. After the LL, angular deviations exceeding  $10^\circ$  persisted in 10 lengthenings. In 3 of these, angulation progressed after the removal of the EF. No patient with a straight lengthening at the completion of LL developed angular deviations. Late corrective osteotomies were performed in 5 patients.

Bone grafting of the distraction gap was performed in 2 femurs and in 1 tibia. 1 patient, with a pseudarthrosis of the fibula, was bone-grafted and internally stabilized 4 years after LL, due to pain from the ankle joint.

### External fixator

1 Orthofix screw fractured during the consolidation period and was replaced.

### Fractures

After the removal of the EF, 3 patients sustained 4 fractures. 1 patient subjected to bilateral lengthening fractured both femurs on different occasions, after moderate trauma, which necessitated open reduction

and internal fixation. 1 patient fractured his femur in an automobile accident 3 days after removal of the EF; the fracture healed in EF with 1 cm loss of length. 1 patient sustained an undisplaced fracture through the distal pin-holes of the tibia, which healed without any active treatment.

18 patients were subjected to 23 surgical procedures, after the lengthening had been completed. A total of 203 operations was performed in these 45 patients and only 1 patient suffered no observable complication.

## Discussion

Callus distraction, first introduced by Ilizarov, has gained increasing recognition and has provided orthopedic surgeons with a tool capable not only of correcting limb length inequality but also of treating other severe skeletal disorders (Green 1991, Cattaneo et al. 1992, Grant et al. 1992, Miller and Bell 1992, Rajacich et al. 1992). The method is, however, associated with a considerable number of complications and the learning curve is steep (Paley 1990, Eldridge and Bell 1991).

Considerable lengthening is possible and LLI can, in most cases, be corrected (Dal Monte and Donzelli 1987, Aldegheri et al. 1989). Less attention has been paid to the cost, complication rate and end-result regarding this goal.

In our material the complications seemed to be associated with the technique rather than the cause of leg shortening or the amount of lengthening achieved. With increasing experience, the number of more severe complications appears to have diminished. The adverse effects of LL could in most cases explain the patient's dissatisfaction with the result.

Not all complications affect the end-result and several authors have proposed that a distinction should be made between the severity of the complications and the ensuing end-result (Wagner 1972, Paley 1990). Mild complications (problems) resolve without surgery. Moderate complications (obstacles) necessitate further surgery to avoid sequelae. Severe complications (complications) compromise the end-result and are either manageable or untreatable.

## Problems

The number of pin-tract infections in our material exceeds the number reported in other studies (Dahl and Fischer 1991, Eldridge and Bell 1991). This can be explained by our liberal policy regarding diagnoses of infections and administration of oral antibi-

otics, which did not appear to have any adverse effects. Deep infections and osteomyelitis were not recorded. Proper placement and care of the pins/screws throughout the lengthening procedure are essential (Green 1981).

Restricted joint motion was found during most lengthenings. Flexion contractures of the hip and knee are potentially harmful, since they predispose to dislocations and equinus (Jones and Moseley 1985, Ganel and Blankstein 1987). The contractures appeared after varying periods of lengthening and had an unpredictable onset. When detected, lengthening should be reduced or stopped and intensive physiotherapy commenced, preferably with the patient in hospital. Surgery may prove necessary. Dysplastic hip joints should be treated before lengthening or externally stabilized during lengthening. In patients with unstable knee joints, external stabilization of the knee should be considered. In tibial lengthenings exceeding 5-6 cm, the foot is now recommended to be externally secured in a plantargrade position (Lehman et al. 1991).

Decreased knee flexion is immediately registered in the postoperative period, even though the knee can be fully flexed during surgery. It is often caused by a transfixation of the quadriceps and fascia lata. A more proximal placement of the screws is recommended. In approximately 2 of 3 cases, a full range of motion was regained during the months following the removal of the EF.

## Obstacles

Angular deviations (Dahl and Fischer 1991, Guidera et al. 1991), present in more than half of our LLs, were usually caused by tense muscles bending the screws. Circular frames permit gradual correction and can consequently better control angular deviations, but they are less well-tolerated in the femur.

A presetting in valgus prior to femoral lengthening may prevent subsequent varus deviation (Price and Mann 1991). The rigidity of the external fixator is enhanced by increasing the number of bone screws and by maintaining a short distance between the bone and the fixator (Behrens and Johnson 1989). Unacceptable deviations were corrected during lengthening. This did not seem to affect the healing index, and further lengthening was possible.

Angulations occurring after the removal of the EF are probably caused by premature removal. They did not appear to be a serious problem in our series.

A good knowledge of axial anatomy is essential if one is to avoid vascular and nerve injuries and any impairment must be recognized promptly, evaluated and, if necessary, dealt with.

Premature closure of the osteotomy was observed in patients who distracted at a slower rate than planned or had stopped distraction for one reason or another (Paley 1990). Lengthening could be continued without adverse effects after both closed and open re-corticotomy.

The cause of non-union or delayed union is not obvious. The dislocation of the bone ends during surgery and a primary separation in the corticotomy seemed to delay bone healing. Other causes could be an instability of the fixator, an immobility of the patient during LL, infections, smoking and intrinsic factors.

### Complications

These should and could, in most cases, be avoided. The surgeon must be well acquainted with the technique and its pitfalls, must be able to confer with the patient and be at hand when problems occur. Most complications become severe if neglected.

Late fractures reflect the problem of determining the strength of the regenerated bone by plain radiographs. CT and MRI scans have displayed irregular new bone formation and prolonged remodeling of the new bone (Tjernström et al. 1992). The strength of the regenerated bone was found to be equal to that of the normal skeleton, if consolidated (Schickendantz et al. 1992). The late fractures were treated with conventional techniques and healed uneventfully.

Our knowledge regarding the effect of lengthening on muscles is limited. Muscle fibrosis subsequent to lengthening has been demonstrated (Kenwright 1992). This may explain why approximately every third patient had a certain restriction in joint mobility at follow-up.

The long-term effects of lengthening on joints have not been fully elucidated and no conclusions about the single case with late hip dysplasia can be drawn.

This material cannot identify any single group of patients more prone to complications where lengthening is inadvisable. In every case of planned lengthening the surgeon must be aware of the risk of complications. By registering the complications and recognizing the problems these can be reduced and thus the number of satisfied patients will increase. Despite all the problems presented, our conclusion is that callus distraction is a major achievement in orthopedic surgery, but it should be centralized.

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## Legend to Table 1.

A Case	P Time in hospital, subsequent lengthening, days	AI Total number of operations
B Sex	Q Total time in hospital, days	AJ Lengthened, cm
1 female	R Nerve Impairment	AK Time with external fixator, days
2 male	1 sensory	AL Healing index, days/lengthened cm
C Age, years	2 motor	AM Follow-up, years
D Diagnosis	S Angulation	AN LLI after lengthening, cm
1 congenital	1 varus	AO LLI radiologic at follow-up, cm
2 post-traumatic	2 valgus	AP Persistent angulation
3 epiphyseal injury	3 dorsal	1 varus
4 sequel of polio	4 ventral	2 valgus
5 sequel of osteomyelitis	T Degree of angulation	3 dorsal
6 sequel of tumor	1 <20	4 ventral
7 Mb Ollier	2 >20	AQ Degree of angulation
8 Spastic hemiplegia	3 >30	1 <20
9 Short stature	U Premature closure	2 >20
E Height	V Pin-tract infection	3 >30
F LLI clinical	W Restricted ROM during lengthening	AR Restricted ROM at follow-up
G LLI radiologic	1 hip	1 hip
H Side	2 knee	2 knee
1 dx	3 ankle	3 ankle
2 sin	X Flexion contracture	AS Operations after the lengthening
I Previous operations	Y Equinus	1 lengthening
1 lengthening	1 yes	2 epiphyseodesis
2 shortening	2 prophylactic external fixation	3 osteotomy
3 osteotomies	Z Subluxation	4 tendon lengthening
4 tendon lengthening	AA Delayed union	5 foot surgery
5 foot surgery	AB Fracture	6 ORIF
J Restricted ROM	AC-AH Additional operations during lengthening	7 arthrolysis
1 hip	1 angular and/or fixator correction	8 arthrodesis
2 knee	2 re-corticotomy	9 Salter osteotomy
3 ankylosis knee	3 Achilles tendon lengthening	AT Subjective evaluation of the lengthening
4 ankle	4 tendon lengthening	1 dissatisfied
5 ankylosis ankle	5 bone grafting	2 undecided
K Anesthesia	6 external fixation of the foot	3 satisfied
1 general	7 neurolysis	4 additional lengthening
2 epidural	8 internal fixation	5 excluded
L Operation time, min	9 external fixation	6 lost at follow-up
M Peroperative blood loss, mL	10 minor surgery	AU Case number in Tjernström and Rehnberg (1994).
N External fixator		
1 Orthofix		
2 Ilizarov		
3 M/S		
4 Hoffmann		
O Morphine postoperatively		