Soft tissue contractures of the knee or ankle treated by the Ilizarov technique

High recurrence rate in 26 patients followed for 3–6 years

Shier-Chieg Huang

We used Ilizarov frames in 26 patients for correction of severe contractures in 10 knees and 19 ankles. All patients had good initial correction. 2 patients developed posterior subluxation of the knee and 2 patients developed anterior subluxation of the ankle. At a minimum of 3 years' follow-up, 11 contractures had recurred. All patients except 1 had persistent restriction of motion. Considering the final position, improvement of motion and complications, we obtained an excellent result in 1 patient, good in 13, fair in 11, and a poor result in 1. Better results were obtained in patients with posttraumatic contractures than with other etiologies. There were also better results in correcting equinus contracture of the ankle than in knee flexion contracture.

Department of Orthopedic Surgery, National Taiwan University Hospital, No. 7, Chung-Shan South Road, Taipei, Taiwan
Tel +886 2-3219773. Fax-3219773
Submitted 95-10-21. Accepted 96-07-04

Trauma, neuromuscular disorders, congenital anomalies, burns and other diseases can cause contracture of the lower extremities. In mild cases, serial casting, corrective bracing (Bonutti et al. 1994), or soft tissue release (Heydarian et al. 1984) are effective. In severe cases, the use of tissue expander (Bassett et al. 1993), extensive soft tissue release (Porat et al. 1995), corrective osteotomy (Leong et al. 1982, Hang 1983), shortening osteotomy (Saleh et al. 1989), and even microvascular free tissue transfer (Ohmori 1982) have been used.

The Ilizarov technique can be used to correct joint contractures and deformities, but the technique, results and complications are not well known (Grill and Franke 1987, Ilizarov 1990, Calhoun et al. 1992, Grant et al. 1992, Hägglund et al. 1993, Paley 1993, Herzenberg et al. 1994, Damsin and Ghanem 1996). We report our experience with correction of severe soft tissue contractures of the knee and ankle by the Ilizarov technique.

Patients and methods

Between 1988 and 1991, we used the Ilizarov technique in 26 patients with severe contracture of the knee and/or ankle joint (Table 1). 3 patients had contractures of both the knee and ankle. The patients had no gross deformities of bone or joint surfaces.

Knee contractures

10 patients (cases 1–7, 24–26) had flexion contracture of the knee. Their median age was 13 (2–31) years. The etiologies were congenital anomalies in 4 patients, tumor resection in 3, trauma in 1, poliomyelitis in 1, and burns in 1. The degree of flexion contracture of the knee was measured clinically along the middle plane of the lateral femorotibial axis, with full extension of the knee as zero degree. The median flexion contracture was 55° (40°–135°). The total motion was measured from maximal extension to maximal flexion of the knee and was preoperatively a median of 50° (10°–100°). Muscle power was graded from 0 to 5 degrees. All patients had various degrees of muscular imbalance, with stronger flexion than extension. Associated problems included leg-length discrepancy in 6 patients, femoral fracture in 1, flexion contracture of the hip in 1, malunion of the other hip in 1, hip dislocation in 1, hemangiolymphangioma of the thigh in 1, and patellar subluxation in 1. The duration of the contracture ranged from 7 months to more than 20 years.

For correction of the contracture, 4 levels of fixation were set up across the knee joint. At the thigh, a 120° femoral arch with 2 half-pins or a full ring with 2 olive wires was used proximally, while a full ring with 2 olive wires was used distally. At the lower leg, 2 full rings with 2 olive wires or 1 half-pin and 1 olive wire in each ring were used. Medial and lateral hinges connecting the femoral and tibial rings were set at ap-

Table 1. Clinical data of all patients

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1	1	2	3	1	50	20	1:3	1	1.8	2	0	2	3	1,2	0	6.0	20	20	30	0	3
2	1	26	6	1	50	100	4:5	1, 8	1.3	2	9	0.8	1	0	0	3.7	0	150	50	50	1
3	1	11	5	1	135	20	2:4	0	1.0	3	0	6	1	1	0	3.4	60	10	75	-10	4
4	1	3	3	1	60	50	1:3	0	2.9	2	0	4	2	2	0	3.2	0	40	60	-10	3
5	2	12	5	1	45	75	1:4	1, 10	4.0	2	0	2	2	4	0	3.3	0	20	45	-55	3
6	2	14	5	1	80	20	1:4	1	2.6	2	0	3.5	4	1	0	3.6	20	20	60	0	3
7	1	25	1	1	70	10	3:4	4	0.6	2	4	1	1	1	0	3.6	20	10	50	0	3
8	1	10	1	2	50	0	0:1	3	1.0	3	0	2	4	1,3	2	3.9	0(20)	0	50	0	3
9	1	6	1	2	50	0	1:4	2	1.0	3	3	2.5	4	0	0	3.8	0	10	50	10	2
10	1	9	1	2	50	0	1:4	0	5.0	3	0	2	4	0	0	3.2	0	20	50	20	2
11	2	32	7	2	50	0	0:0	3	4.1	3	0	2	2	0	0	3.2	0	20	50	20	2
12	1	9	1	2	30	20	1:4	0	1.5	2	0	1	2	1	0	3.2	20	20	10	0	3
13	1	29	1	2	30	20	1:4	4	1.0	1	4	4.5	1	0	0	4.5	0	30	40	10	2
14	1	6	1	2	20	10	2:2	3	0.6	1	0	2	2	0	0	3.2	0	20	30	10	2
15	1	21	1	2	40	10	1:3	1, 2	1.0	1	1 2	2	1	0	0	4.5	0	10	40	0	2
16	1	21	1	2	20	20	1:4	2	0.6	1	1	2	1	0	0	3.9	0	20	20	0	2
17	2	46	1	2	20	30	1:4	2	0.6	1	1	2	1	0	0	3.7	0	30	20	0	2
18	1	34	1	2	25	30	1:4	2	0.6	1	1	3	1	1	0	3.9	20	20	5	-10	3
19	2	27	2	2	30	30	2:4	1	20+	1	2	2	1	0	0	4.7	0	30	30	0	2
20	2	56	1	2	30	20	2:4	5	0.6	2	3	2.5	1	0	0	3.2	0	20	30	0	2
21	1	26	2	2	20	30	1:4	1	20+	1	2	2.5	1	1	1	3.2	0(20)	30	20	0	3
22	2	28	1	2	50	0	1:4	6	1.8	3	6	2	2	0	0	3.5	0	20	50	20	2
23	2	22	2	2	30	40	1:4	1	20+	1	2	3	1	1	1	3.6	0(30)	40	30	0	3
24	1	31	2	1	95	55	1:3	1, 7	20+	2	5,7,8	3	4	0	0	3.2	0	55	95	0	2
	1	31	2	2	35	30	1:3	1, 7	20+	2	5,7,8	3	4	0	0	3.2	0	30	35	0	2
25	2	9	4	1	40	50	1:4	1, 11	8.9	2	0	2	4	0	0	3.2	0	50	40	0	2
	2	9	4	2	50	0	1:4	1, 11	8.9	2	0	2	4	0	0	3.2	0	20	50	20	2
26	2	15	3	1	50	70	2:4	9	14.9	3	0	2.5	4	1,5	0	4.0	20	20	30	-50	3
	2	15	3	2	50	0	2:4	9	14.9	3	0	2.5	4	1	0	4.0	20	20	30	20	3

A Case
B Sex
- 1 male
- 2 female

C Age (years)
D Etiology
- 1 trauma
- 2 sequel of poliomyelitis
- 3 arthrogryposis
- 4 nail-patellar syndrome
- 5 tumor resection
- 6 burn
- 7 paraplegia

E Type of contracture
- 1 flexion of knee
- 2 equinus of ankle

F Preop. position (degrees)
knee: flexion contracture
ankle: contracture in plantar flexion
G Preop. total arc of motion (degrees)
H Muscle balance (muscle power: grade 0–5)
knee: extension:flexion
ankle: dorsiflexion:plantar flexion
I Associated problems
- 0 no associated problems
- 1 leg-length discrepancy
- 2 tibial defect
- 3 severe scar
- 4 femoral fracture
- 5 tibial fracture
- 6 peroneal nerve injury
- 7 flexion contracture of hip
- 8 malunion of other hip
- 9 hip dislocation
- 10 hemangiolymphangioma
- 11 patellar subluxation

J Duration of contracture (years)
K Hinge
- 1 natural
- 2 rotating
- 3 rotating with wire

L Concomitant procedures
- 0 no concomitant procedure
- 1 bone transport
- 2 leg lengthening
- 3 tibial fracture fixation
- 4 femur fracture fixation
- 5 osteotomy of hip
- 6 tenotomy of toe flexor
- 7 hamstring release
- 8 Tendo Achilles lengthening
- 9 femoral lengthening of other limb

M Correction period (months)
N Fixation after correction
- 1 Ilizarov
- 2 cast
- 3 brace
- 4 cast and brace

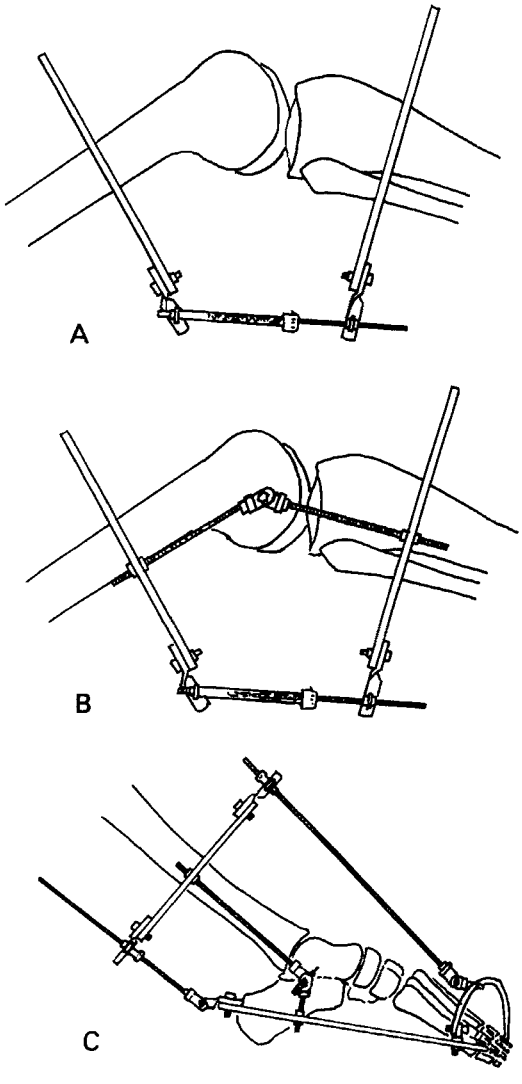
O Complication
- 0 no complication
- 1 recurrence of contracture
- 2 subluxation
- 3 fracture of tibia
- 4 instability of knee
- 5 pin tract infection

P Subsequent operation
- 0 no subsequent operation
- 1 Tendo Achilles lengthening
- 2 ankle fusion

Q Follow-up period (years)
R Final position (degrees)
knee: flexion contracture
ankle: contracture in plantar flexion
( ): before subsequent operation
S Final total arc of motion (degrees)
T Improvement in position (degrees)
U Improvement in total arc of motion (degrees)
V Result
- 1 excellent
- 2 good
- 3 fair
- 4 poor

proximately the axis of rotation of the knee joint (Figure 1). The center of rotation was determined by temporary insertion of a wire at the intersection of the posterior cortex of the femoral shaft and intercondylar notch, and confirmed by fluoroscopy. This kind of hinge allows rotation only (rotating hinge). 2 patients retained the wire, which was tensioned and fixed to the hinges, for better control of stability and motion (rotating hinge with wire). 1 or 2 distraction rods at the posterior aspect of the knee were used (Figure 2). Over-distraction (0.5 cm) of the joint space was done acutely. Concomitant treatments included femoral

Figure 1. Types of hinge.



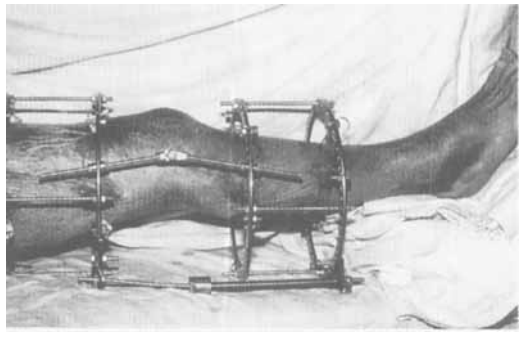
A. Natural hinge: The axis of rotation of the joint is used as hinge.

B. Rotating hinge: Hinges connecting the upper ring of the tibia and lower ring of the femur are located at the axis of the rotation of the knee joint.

C. Rotating hinge with wire: The wire passing through the axis of rotation is connected by a rod with a slot to the rotating hinges and tensioned.

Figure 2. Case 2. 26-year-old man with severe burn of right lower extremity and fracture of left hip after a fire accident.

Because of leg-length discrepancy and scarring of right knee, a flexion contracture of 50° developed. There was thick keloid tissue in the popliteal area.



The Ilizarov frame with a rotating knee hinge. The knee was corrected to full extension 3 weeks later and the keloid tissue behind the right knee disappeared. 3 years and 8 months after treatment, the patient had a straight knee and normal motion.

fracture fixation, osteotomy of the hip, hamstring release, Tendo Achilles lengthening, and femoral lengthening of the other limb. 6 patients had an associated leg-length discrepancy that was not treated, either because the patients were too young for such an operation or they desired a shorter treatment time.

Distraction was started as soon as the postoperative pain subsided, at the rate of 1 mm per day at the level of the knee, which corresponded to 3–4 mm per day at the distraction rod, with the rate modified according to the patient's comfort. The median duration of correction was 2.3 (0.8–6.0) months. The Ilizarov device was kept in place for 1–2 months after the contracture had been corrected, if the patient tolerated the device. After removal of the device, additional maintenance was provided by casting in 2 patients, by bracing in 1, and by casting and bracing in 4. 3 patients had no further immobilization. The duration of casting was 4–6 weeks and for bracing 2–3 months. The patients were encouraged to walk on the treated limb with the help

of bilateral axillary crutches. Range-of-motion exercise was begun after removal of the Ilizarov device and cast, and during brace immobilization.

Ankle contractures

19 patients (cases 8–26) had equinus contracture of the ankle. Their median age was 22 (6–56) years. The etiologies were trauma in 12 patients, poliomyelitis in 4, congenital anomalies in 2, and paraplegia in 1. The degree of equinus contracture of the ankle was measured clinically along the middle plane of the lateral aspect of the leg and plantar surface of the foot, with neutral position of the foot as zero degree. The median equinus contracture of the ankle was 30° (20°–50°). Total motion was measured clinically from maximal dorsiflexion to maximal plantar flexion of the ankle and the preoperative median was 20° (0°–40°). All patients also had various degrees of muscular imbalance, with stronger flexion than dorsiflexion. Associated problems included a tibial bone defect in 5 patients, leg-length discrepancy in 6, moderate or severe scarring of the leg in 3, femoral fracture in 1, tibial fracture in 1, peroneal nerve injury in 1, flexion contracture of the hip in 1, hip dislocation in 1, and patellar subluxation in 1. The history of disease ranged from 7 months to more than 20 years.

For correction of the contracture, 2 full rings with 2 olive wires or 1 half-pin and 1 olive wire in each ring were used at the tibia. At the foot, 2 half rings connected by 2 plates were used, with 2 wires transfixing the calcaneus and 1 wire transfixing the metatarsals. In 9 patients, no hinge was used. In these patients, the ankle joint of the patient was used as the hinge (natural hinge). In the remaining 10 patients, medial and lateral hinges connecting the tibial and foot rings were set at the axis of rotation of the ankle, which was located in the talar body near its inferior aspect. In 6 of these 10 patients, the hinge wire was retained (Figure 1). Pull constructs with 1 or 2 rods were set at the anterior aspect of the ankle joint. The pulling rods exerted the main correcting force. One distraction rod was also set at the posterior aspect of the ankle joint to help correction. Over-distraction (0.5 cm) of the joint space was done acutely. Concomitant treatments included bone transports in 4 patients, leg lengthenings in 4, fracture fixations in 3 (1 in femur, 2 in tibia), tenotomy of the toe flexors in 1, osteotomy of the hip in 1, hamstring release in 1, and Tendo Achilles lengthening in 1. In these cases, the frames were modified for the specific purpose. Correction was started as soon as postoperative pain subsided with the rate of correction set at 1 mm per day at the level of the ankle joint, which corresponded to 3–4 mm per day at the pulling rod and 2 mm per day at the distraction rod, with the rate modified according to the status of correction and the patient's comfort. The median duration of correction was 2.0 (1–4.5) months. The Ilizarov device was kept in place for 1–2 months after the contracture had been corrected, if the patient tolerated the device. After removal of the device, additional maintenance was provided by casting in 4 patients, and casting and bracing in 6 patients. 9 patients had no further immobilization. The duration was 4–6 weeks for casting and 2–3 months for bracing. The patients were encouraged to walk on the treated limb with help of bilateral axillary crutches. Range-of-motion exercise started after removal of the Ilizarov device and cast, and during brace immobilization.

Evaluation

Results were graded as excellent, good, fair and poor. An excellent result was considered as less than 5° of residual deformity, less than 10° difference in motion when compared with the contralateral normal limb, and no complications. A good result was defined as less than 15° of residual deformity, motion equal to or greater than before treatment, and only minor complications which did not affect outcome or require extensive intervention. A fair result was defined as less than 30° of residual deformity, motion equal to or less than before treatment, and serious complications. Complications that were either major and temporary, or minor and permanent, were considered to be serious. Those patients who needed subsequent operation to achieve satisfactory results were grouped in this class. A poor result was defined as more than 30° of residual deformity, decreased motion, and severe complications requiring major surgery or resulting in a major permanent sequel.

Statistics

Since the sample size was small, nonparametric statistics were chosen. The Shapiro-Wilk statistic was used to test the normality of continuous scaled variables, i.e., age, duration of contracture, preoperative and final position and motion, correction period, improvement in position and motion, and follow-up period. The Wilcoxon signed-rank test was used to evaluate the median difference of preoperative and final position and motion among 2 types of contracture. Fisher's exact test was used to examine the association between recurrence of contracture and sex, types of contracture, kinds of fixation after correction, or etiologies of contracture, respectively. The Kruskal-Wallis test was used to detect the association between the explanatory variables and the result. The significance level of the hypothesis test was chosen as 0.05.

Results

We obtained an excellent result in 1 patient, good in 13, fair in 11, and poor in 1 patient. The etiology and type of contractures seemed to relate to the result. Better results were obtained in patients whose contractures were secondary to trauma (good in 9, fair in 4). Sequel of poliomyelitis (good in 2, fair in 2), congenital anomaly (good in 1, fair in 3), or tumor resection (fair in 2, poor in 1) had less favorable results (Table 2). Patients with equinus contracture of the ankle had better results (good in 13, fair in 6) than those with flexion contracture of the knee (excellent in 1, good in 2, fair in 6, poor in 1). The duration of contracture and the age showed no obvious association with the result of treatment.

Table 2. Relationship between etiology and result of treatment

Etiology	Excellent	Good	Fair	Poor
Trauma	0	9	4	0
Sequel of poliomyelitis	0	2	2	0
Congenital anomaly	0	1	3	0
Tumor resection	0	0	2	1
Burn	1	0	0	0
Paraplegia	0	1	0	0
Total (pts)	1	13	11	1

Knee contractures

The median follow-up period was 3.5 (3.2–6.0) years. The flexion contractures in all 10 patients were initially corrected to full extension with the Ilizarov device. At final follow-up, median flexion deformity was 10° (0°–60°), with 5 patients having no recurrence of the contracture. Median improvement of flexion deformity was 50° (30°–95°) ($p = 0.002$). Median motion was 20° (10°–150°), and was improved in 1, not changed in 5, and decreased in 4 patients. Median improvement of motion was 0° (-55°–50°). Only case 2 (burn patient) achieved and maintained full correction and full range of motion (Figure 2). This was the only excellent result in the series. 5 patients with a median age of 12 (2–25) years had a recurrence of the flexion deformity. Case 3 could not attend the clinic regularly during correction. He also refused immobilization after removal of the device. Because of his fear of pain, he did not perform any stretch exercises, and the knee flexion contracture recurred. This was the only poor result in the series. Cases 1 and 4 developed posterior subluxation of the tibia (three-quarters and half of the tibial plateau, respectively) during correction. The subluxations were not treated, while the devices were in place. After removal of the devices, the limbs were kept in cast and brace. At final follow-up, the subluxation had completely resolved, although there was a recurrence of the flexion contracture. Case 5 had excessive posterior laxity of the knee that may have been due to overdistraction of the joint by misplacement of hinges too anteriorly. The patient feels pain in the knee which needs a brace for protection.

Ankle contractures

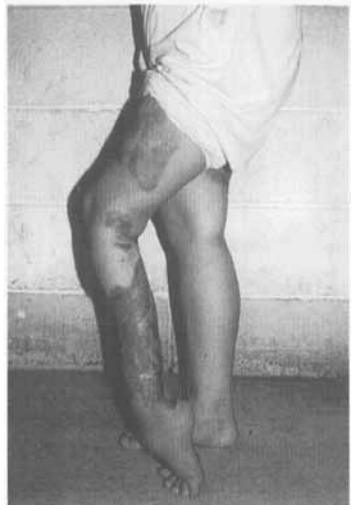
The median follow-up period was 3.6 (3.2–4.7) years. The equinus contractures in all 19 patients were corrected to dorsiflexed position with the Ilizarov device. At final follow-up, the median equinus contracture was 0° (0°–20°). In 16 patients, the deformity had resolved completely (2 had received Tendo Achilles lengthening for recurrence of equinus deformity). The median improvement in the equinus deformity was 30° (5°–50°) ($p = 0.0001$). Motion was 20° (0°–40°), and had improved in 8 patients, not changed in 10, and decreased in 1. The median improvement in motion was 0° (-10°–20°) ($p = 0.02$). 6 patients with a median age of 19 (9–34) years had a recurrence of the contracture. Case 8 suffered a fracture of the lower tibia when we attempted manual correction of recurrent equinus contracture (Figure 3). The fracture healed in a posteriorly angulated position. The foot was plantigrade thereafter, but the patient underwent ankle fusion later due to a recurrence of the equinus contracture. 2 patients had subsequent Achilles tendon lengthening to obtain plantigrade feet, but 3 patients refused tendon lengthening. Cases 8 and 10 had anterior subluxation of the talus (one-fourth of the talar dome), while 1 case showed mild narrowing of the joint space during correction. After removal of devices and immobilization of the ankles in the cast and brace, the subluxation gradually resolved.

Discussion

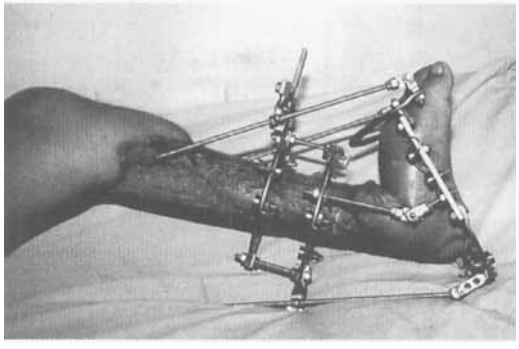
Equinus deformities of the ankle, especially those of traumatic etiology, were mostly related to faulty positioning of the foot in equinus and subsequent contracture of the calf muscles during the primary treatment. In these cases it was easy to stretch out the deformity and maintain the correction.

The contractures of the knee and the ankle had improved, but the total motion was only slightly improved (ankle) or unchanged (knee). However, the range of motion of the joints was shifted to a more functional position. It is difficult to maintain joint motion during correction because of pain, poor compliance of the patient, and the complexity of design

Figure 3. Case 8. 10-year-old boy, with severe avulsion injury to his left leg from a car accident. Multiple debridements and skin grafts have been performed.



Equinus contracture of left foot developed with poor scar tissue over posterior heelcord area.



Over-correction was achieved 2 months after application of an Ilizarov frame with rotating ankle hinge and hinge wire.

for concomitant correction, i.e., lengthening or bone transport. Patients should therefore expend much effort and more time in rehabilitation after removal of the frame. Physiotherapy and cooperation of the patients are important both during correction and after removal of the device. After prolonged illness and treatment, normal muscle strength and range of joint motion may not have been regained, even after vigorous exercise (Herzenberg et al. 1994).

There are few descriptions of a hinge for correction of joint deformity (Volkov and Oganesyan 1987, Herzenberg et al. 1994, Damsin and Ghanem 1996). Usually, a rotating hinge or natural hinge is used. Since the instant centers of rotation of the knee and the ankle joints are not fixed (Hollister et al. 1993), there is unphysiological motion in the joint with the fixed axis of the hinge in an Ilizarov frame. Crushing of adjacent articular surfaces may occur and result in stiffness and degenerative joint changes. This can be avoided by slight over-distraction of the joint (Herzenberg et al. 1994, Damsin and Ghanem 1996). Volkov and Oganesyan (1987) have designed several types of hinges to try to imitate the gliding and rotation motion of the knee and rotation motion of the ankle, and have reported good results. They used a hinge wire routinely together with the hinged distraction principle. Under such conditions, the joint may rotate more physiologically. We used hinges with wire in 2 knees and 6 ankles. Erosion and infection around the pin were common in these patients, and we therefore do not recommend hinges with wire. Misplacement of the hinges can also cause subluxation of the joint, crushing of articular surfaces or over-distraction of ligamentous structures, which may result in excessive laxity and instability. In our series, 2 cases of posterior subluxation of knees and 2 cases of anterior subluxation of the ankles were noted, which could have been the results of inappropriate positioning of hinges. The cases with subluxation of the ankle also had a hinge wire. After removal of the frame, the joints returned gradually to their anatomical position. In the remaining 8 cases, this did not happen, since we set the hinge more accurately and adjusted the position of the hinges more often during correction, in accordance with the radiogram of the joints. Subluxation did not occur in cases with natural hinges. With normal joint structure, correction of the deformity may occur along the axis of rotation.

A hinge that is suitable for the Ilizarov frame and mimicks the physiological joint motion should be developed. Careful use of natural hinges may be another alternative. Ilizarov used a natural hinge or temporarily removed the hinge during correction to allow restoration of the normal joint position. Once subluxation of the joint is detected during correction, it can be reduced by means of the existing Ilizarov frame and addition of a pull construct, or change of position of hinges (Damsin and Ghanem 1996). However, our observations show that the subluxation may spontaneously reduce after removal of the fixation device.

We did not experience nerve injury either intraoperatively or during correction. We adjusted the rate of correction to 1 mm per day at the most critical point, e.g., neurovascular structures of the knee and ankle (Herzenberg and Waanders 1991).

Recurrence of contractures was common. The causes could be inadequate stretch or regeneration of soft tissues, muscular imbalance, poor positioning of the limb, and growth. Low-load prolonged stretch is preferred to high-load brief stretch (Light et al. 1984).

In distractional neogenesis, the soft tissue will be stretched first and will then regenerate and remodel (Kochutina 1990). Nearly normal tissue may respond better than fibrotic or atrophic tissue.

The method, time schedule, morbidity and complications should be explained adequately to the patient before operation. Cooperation of the patients and their families is important. The possibility of muscle balancing and other procedures must also be pointed out to the patients before correction, to prepare them for an eventual secondary operation for complications. Because the result is related to the etiology and location of the disease, the presence of associated problems, experience of the surgeons and cooperation of the patients, both the surgeons and the patients should have a realistic goal at the outset. According to our early experience, a satisfactory outcome is achieved in half of the patients. With better selection of patients, better design, adequate physiotherapy and bracing, the results can be improved.

Acknowledgments

The author thanks Drs. K N Kuo, P Q Chen, C L Wang, C Lin, C C Lin, C D Wu, and Y H Heish for referral of patients, and Dr. Charng-Er Shyu for statistical analysis.

References

Bassett G S, Mazur K U, Sloan G M. Soft-tissue expander failure in severe equinovarus foot deformity. J Pediatr Orthop 1993; 13 (6): 744-8.

Bonutti P M, Windau J E, Ables B A, Miller B G. Static progressive stretch to reestablish elbow range of motion. Clin Orthop 1994; 303: 128-34.

Calhoun J H, Evans E B, Herndon D N. Techniques for the management of burn contractures with the Ilizarov Fixator. Clin Orthop 1992; 280: 117-24.

Damsin J P, Ghanem I. Treatment of severe flexion deformity of the knee in children and adolescents, using the Ilizarov technique. J Bone Joint Surg (Br) 1996; 78 (1): 140-4.

Grant A D, Atar D, Lehman W B. The Ilizarov technique in correction of complex foot deformities. Clin Orthop 1992; 280: 94-103.

Grill F, Franke J. The Ilizarov distractor for the correction of relapsed or neglected clubfoot. J Bone Joint Surg (Br) 1987; 69 (4): 593-7.

Hang Y S. Supracondylar genu recurvatum osteotomy in the treatment of flexion contracture of the knee joint. J Formos Med Assoc 1983; 82 (12): 1293-300.

Herzenberg J E, Waanders N A. Calculating rate and duration of distraction for deformity correction with the Ilizarov technique. Orthop Clin North Am 1991; 22 (2): 601-11.

Herzenberg J E, Davis J R, Paley D, Bhave A. Mechanical distraction for treatment of severe knee flexion contractures. Clin Orthop 1994; 301: 80-8.

Heydarian K, Akbarnia B, Jabalameli M, Tabador K. Posterior capsulotomy for the treatment of severe flexion contractures of the knee. J Pediatr Orthop 1984; 4 (6): 700-4.

Hollister A M, Jatana S, Singh A K, Sullivan W W, Lupichuk A G. The axes of rotation of the knee. Clin Orthop 1993; 290: 259-68.

Hägglund G, Rydholm U, Sundén G. Ilizarov technique in the correction of knee flexion contracture: Report of four cases. J Pediatr Orthop Part B 1993; 2 (2): 170-2.

Ilizarov GA. Clinical application of the tension-stress effect for limb lengthening. Clin Orthop 1990; 250: 8-26.

Kochutina L N. [Regenerative myogenesis of the leg muscles during experimental lengthening]. Izv Akad Nauk SSSR 1990; 4 (4): 565-70.

Leong J C Y, Alade C O, Fang D. Supracondylar femoral osteotomy for knee flexion contracture resulting from poliomyelitis. J Bone Joint Surg (Br) 1982; 64 (2): 198-201.

Light K E, Nuzik S, Personius W, Barstrom A. Low-load prolonged stretch vs. high-load brief stretch in treating knee contractures. Phys Ther 1984; 64 (3): 330-3.

Ohmori S. Correction of burn deformities using free flap transfer. J Trauma 1982; 22 (2): 104-11.

Paley D. The correction of complex foot deformities, using Ilizarov's distraction osteotomies. Clin Orthop 1993; 293: 97-111.

Porat S, Mosheiff R, Peyser A. Popliteal pterygium associated with complete amelia of upper limb: early surgical treatment. J Pediatr Orthop 1995; 15 (2): 254-9.

Saleh M, Gibson M F, Sharrard W J W. Femoral shortening in correction of congenital knee flexion deformity with popliteal webbing. J Pediatr Orthop 1989; 9 (5): 609-11.

Volkov M V, Oganesyan O V. Hinged distraction apparatuses to restore movements in the joints. In: External fixation: joint deformities and bone fractures. (Eds. Volkov M V,Oganesyan O V).International Universities Press, Madison, Connecticut, 1987: 75-165.