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ORIGINAL STUDY

Lengthening procedures of small bones of foot and foot stump

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Foot length discrepancy may result from congenital or acquired causes. If the absence of the foot is more proximal than the metatarsal level, push off and foot resilience will be disturbed and rapid walking and spring will be awkward. Those patients have to be fitted with a prosthesis extending above the ankle to the distal leg. The functional impairment and poor cosmetic appearance become social problems especially for adolescents.

Twelve cases underwent a lengthening procedure of small bones of the foot in our clinic since 1995 to lengthen the foot or a foot stump. Results were satisfactory.

INTRODUCTION

Adequate base support is necessary for a stable gait pattern (*3*). Foot length discrepancy may be caused by congenital and acquired causes. Congenital transverse arrest and intrauterine amputations generally occur on the distal parts of the foot (*12, 13*). If the absence is distal to the metatarsal level, there is no disorganisation during ordinary walking, but if it is more proximal, push off and foot resilience will be disturbed and rapid walking and spring will be awkward (*11*). Those patients must be fitted with a prosthesis extending to the ankle or distal leg. This functional impairment and poor cosmetic appearance become social problems especially for adolescents.

Improving the gait and decreasing the demand for prostheses are the main goals with foot lengthening procedures. Cosmetic improvement is also in mind. Solving shoe wear problems, obtaining a wider stump base, and equalising the foot length are the primary side goals.

MATERIALS AND METHODS

Lengthening procedures for the small bones of the foot have been performed on 12 patients in our department since 1995. The patients were classified in three groups according to the site of lengthening.

First group. Hind-foot lengthening : **4 cases** (table I)

Four patients had an amputation at the level of the Chopart joint. Two of them were suffering from burn sequels, they were male and ages were 17 and 15. Two had congenital transverse arrest. One of them was a girl (5 years old) and the other was a boy (6 years old). Calcaneal lengthening procedures were performed to obtain a longer stump basis and to improve gait (fig 1).

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Table I. — Data of the hindfoot group

Patient number	Cause	Age/Sex	Lengthening (cm)	Follow-up (years)	Prosthesis	AOFAS hindfoot-score	GSF
1	Burn sequelae	17/M	4	7	Shoe filling	69/poor	Satisfied with major reservation
2	Burn sequelae	15/M	3.5	6	Shoe filling	50/poor	Satisfied with major reservation
9	Congenital	5/F	4	5	Shoe filling	86/good	Satisfied with reservation
11	Congenital	6/M	3	3	Shoe filling	76/fair	Satisfied with reservation

AOFAS ; American Orthopedic Foot and Ankle Society, GSF ; Grading of Subjective Function.

Fig. 1. — Lateral radiograph of Case 2 before lengthening

Circular and uniplanar fixators were combined while performing the operations. The configuration of the fixator was determined according to the preoperative radiographs and demands of the patients. Under general anaesthesia, three transfixing pins were placed in the anterior part and three others in the posterior part of the calcaneus. A vertical osteotomy was done in the middle of the calcaneal bone. A bilateral, uniplanar fixator with a half ring was placed. The ankle was fixed with a ring at the supramalleolar level (fig 2, fig 3).

Second group. Midfoot lengthening : **7 cases** (table II)

Two patients were girls, 5 were boys. Median age was 9 (± 7) years. Five had a congenital transverse arrest at the level of the Lisfranc joint. Two had a structurally full foot, but they had either an iatrogenic length discrepancy (3.5 cm) after club foot treatment, or a burn sequel (3 cm). One patient had a transverse arrest of his foot but also a tibial length discrepancy and he was unable to bear weight on his foot. The goal was to lengthen the navicular and cuboid bones. This was especially difficult in patients with congenital amputations. Sometimes the unusual shape made it difficult to identify the bones and if the patient was younger than 2 years, navicular and cuneiform ossification centres could not be seen on radiographs. Configuration of the external fixator and the level of the osteotomy was determined preoperatively, according to the demands and the radiographs of the patient. The osteotomy line was positioned at the ossification centres of the bones. At least three pins were placed under general anaesthesia on each side of the predicted osteotomy site. A bilateral, uniplanar fixator was set up after the osteotomy. Lengthening was performed in two stages in two cases with congenital transverse arrest (cases 7 and 10) and in three stages in one case (case 4). In the latter case, the bone structure of the foot was insufficient and the foot was lumpy and so shapeless that a 5-cm fibular autograft from the contralateral side was used as an internal splint to protect the obtained lengthening after the first lengthening procedure (fig 4). The autograft was placed just above the lengthening site, inside a soft tissue bed. It was not resorbed ; on the contrary, bony union between this autograft and midfoot bones was seen after 17 months. Osteotomy was performed on it during the second and third lengthening procedures and callotasis of the graft was performed. After five years, foot length discrepancy in this patient was one cm and the autograft had become one of the

Table II. — Data of the midfoot group

Patient number	Cause	Age/sex	Lengthening (cm)	Follow up (years)	Prosthesis	AOFAS midfoot score	GSF
3	Congenital	5/F	2	3	No prosthesis	67/poor	Satisfied with reservation
4	Congenital	6/M	7 (in three session)	5	No prosthesis	72/fair	Satisfied with reservation
5	Burn sequelae	15M	1.5	3	Shoe filling	59/poor	Dissatisfied
6	Iatrogenic	7/M	4	2	No prosthesis	85/good	Completely satisfied
8	Congenital	7/F	4.6	4	No prosthesis	82/good	Completely satisfied
10	Congenital	9/M	6 (in two session)	3	No prosthesis	72/fair	Completely satisfied
7	Congenital	2/M	5 (in two session)	2	No prosthesis	70/fair	Satisfied with reservation

AOFAS ; American Orthopedic Foot and Ankle Society, GSF ; Grading of Subjective Function.

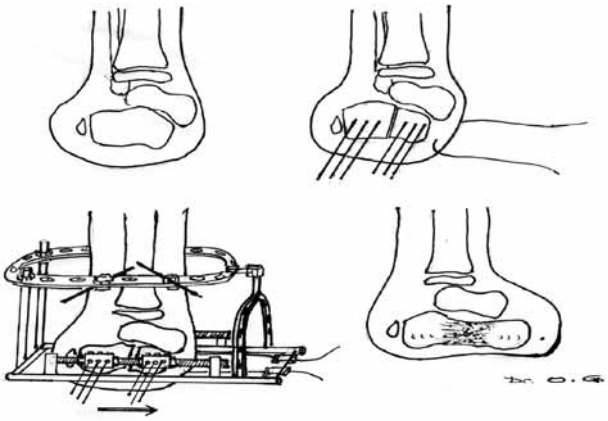

Fig. 2. — Schematic drawing of the external fixator construct in Case 2.

Fig. 3. — Lateral radiograph of Case 2 after lengthening

midtarsal bones with obvious cortical bone and medulla formation (fig 5, 6, 7).

Third group. Forefoot lengthening : **one case** (table III)

This was a young woman of 18 years of age with bilateral short 4th metacarpals and a unilateral short fourth metatarsal bone on the right side. Her 4th toe was lying over the 3rd and 5th toe and she had difficulties wearing shoes (fig 8). At the same time she had considerable cosmetic problems with the appearance of her fingers. Simultaneous lengthening procedures of the metacarpals and the metatarsal bone were done. Unilateral, uniplanar external fixators were used. Two pins were placed at both sides of the osteotomy under general anaesthesia. The external fixator was placed and the osteotomy was performed in the metaphyseo-diaphyseal zone (fig 9).

The lengthening material was designed by Girgin and has been manufactured since the early 80's and used for metacarpals. This was the first time we used this device for metatarsal lengthening.

In all cases, lengthening began on the fourth post-operative day at a rate of 1 mm/day (0.25 mm $\times$ 4 times).

Table III. — Data of the forefoot group

Patient number	Cause	Age/sex	Lengthening (cm)	Follow- up (years)	Prosthesis	AOFAS-LTMI score	GSF
12	Congenital	18/F	1.5	6	No prosthesis	87/good	Completely satisfied

AOFAS-LTMI ; American Orthopedic Foot and Ankle Society-Lesser Toe Metatarsophalangeal-Interphalangeal, GSF ; Grading of Subjective Function.

Fig. 4. — Initial clinical appearance of Case 4

Fig. 5. — Lateral radiograph of Case 4, 1 year after the procedure.

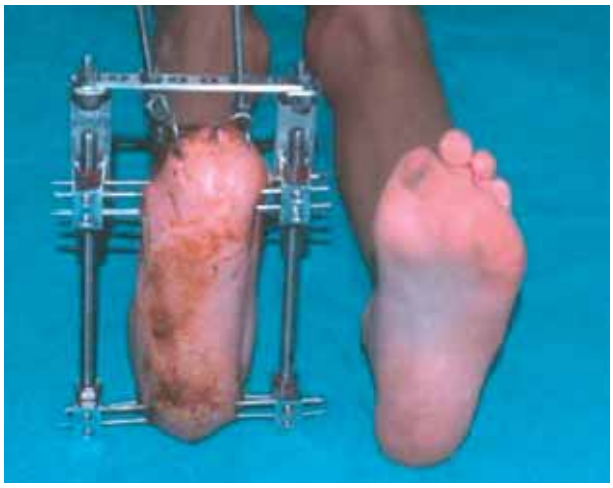

Fig. 6. — Clinical appearance of Case 4, at the end of the third procedure.

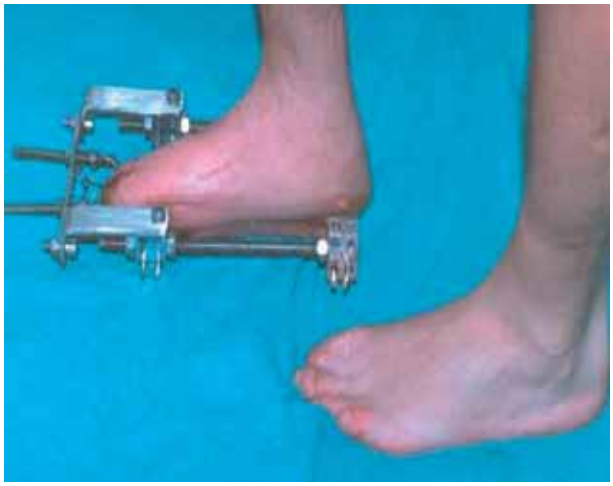

Fig. 7. — Clinical appearance of Case 4, at the end of the third procedure.

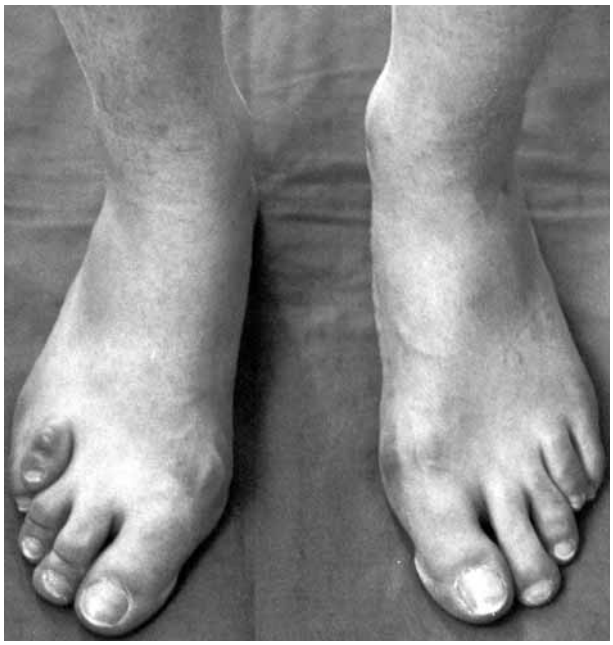

Fig. 8. — Clinical appearance of Case 12, before the operation

Fig. 9. — Clinical appearance of Case 12, three months after the procedure.

When the predicted length was obtained, lengthening was stopped and the external fixator was left until consolidation or replaced by a cast. Afterwards splints were used during 6 more months, in patients presenting a tendency to develop recurrent deformities, as in burn sequelae.

Outcome evaluation was done by establishing the American Orthopaedic Foot and Ankle Society Score (AOFAS score) for ankle-hindfoot complex in the patients of the first group, for midfoot in the second group and for the lesser toe metatarsophalangeal-interphalangeal in the last group (*10*). Results between 90 and 100 points were regarded as excellent, 80 and 89 as good, 70 and 79 as fair and if it was less than 70 as poor (*1*).

Patients' satisfaction was evaluated with grading of subjective function (GSF) (*1, 5*).

RESULTS

The mean lengthening in the hindfoot group was 3.6 cm and the mean follow-up period was 5.2 years. The mean AOFAS score was 70.2 points. Two patients were satisfied with reservation and two with major reservation. They were using a shoe-filling prosthesis and had less disability.

The mean lengthening was 4.3 cm in the midfoot group. Six of the patients were able to discard their prostheses. The mean AOFAS midfoot score was 72.4 points. Three patients were entirely satisfied, and the other three with reservation. In one patient the planned lengthening could not be obtained because of implant failure and a shoe-filling device was needed. He was not satisfied.

In the last patient with the metatarsal and metacarpal lengthening, the score was 87 points for the lesser toe metatarsophalangeal-interphalangeal scale. The amount of lengthening was 1.5 cm on each bone. Shoe wearing and function were improved. She was completely satisfied.

Pin tract infection was a complication of four procedures. Although all the patients faced pain during the postoperative period, it was temporary and relieved after consolidation. Lengthening procedures were done in three sessions in one patient and two sessions in two others with congenital anomalies.

DISCUSSION

External fixation as a method of bone lengthening is widely used in the world, in fracture treatment and correction of deformity. More than 1600 patients have been treated, using external fixator systems in our clinic since 1979. Approximately half of them have been operated on for bone lengthening procedures. The major group is formed by tibial lengthening cases, followed by femur, forearm, humerus and metacarpal lengthening cases in a decreasing order.

The use of an external fixator (EF) for foot problems began in our clinic in 1992 to correct foot contractures due to burn sequelae (*2*) and it was later applied to foot length discrepancy, short foot stumps or small metatarsal bones. Experience was gained with the use of external fixators in the treatment of open fractures, pes equinovarus and brachymetatarsia (*4, 6, 8, 9*). Lengthening procedures for foot length discrepancy and foot stumps is not a widespread procedure, and literature is lacking. Lengthening procedures of small bones for anomalies of the hand and foot have been tried and since quite acceptable results were obtained, these procedures were advocated (*9*).

In our department, foot lengthening procedures have been started in 1995, as an attempt to reduce the need for prostheses and to improve the gait and appearance.

Complication rates were the same as with external fixators in any other part of the body (*7, 9, 10*).

Not only length discrepancies but also accompanying deformities existed in our patients. Most of them had congenital anomalies and burn sequelae. They had a high tendency to develop new deformities after treatment. There were very few treatment options available for this group of patients. External fixation systems gave us the chance of correcting the deformities, obtaining the ideal length and preserving the best configuration. Moreover, it was possible to manipulate the configuration and make changes during the treatment.

More than one procedure was needed for the patients with congenital anomalies. One of the patients (case 4) had not only foot length discrepancy but also a congenital short tibia. Proximal tibial epiphyseal lengthening and three sessions of foot lengthening were performed. Two-stage lengthening procedures were needed in the other two patients with congenital deformities.

Good and fair results were obtained in eight patients out of twelve. All the patients but one were satisfied with the results (*1*).

Although the indications are limited, lengthening procedures of the small bones of the foot should be considered as a treatment option for feet with deformities and length discrepancy. Obtaining a painless, plantigrade, functional foot with an ideal length is possible with an external fixator. The technique is difficult, but with good preoperative planning and proper patient selection the success rates in experienced hands will be rewarding.

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