

Reduced lengthening index by use of bifocal osteotomy in the tibia

Comparison of monofocal and bifocal procedures with the Ilizarov external fixator

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ABSTRACT – We lengthened 63 tibial segments in 49 patients, performing a monofocal osteotomy on 31 segments and a bifocal osteotomy on 32 segments. In the monofocal osteotomy group, the average lengthening was 4.8 (2.4–7.1) cm with a lengthening index (LI) of 1.7 (0.9–4.4) months/cm. In the bifocal osteotomy group, the average lengthening was 7.4 (4.9–10.0) cm and with a LI of 1.0 (0.7–2.1) months/cm. The difference in LI between the groups was statistically significant, but more major complications, like persistent ankle joint contracture and pseudarthrosis in the callotasis lengthening zone, occurred with bifocal lengthening.

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Lengthening of the long tubular bones is used in both pediatric and adult orthopedics to treat large differences in leg length, short stature, axial deformities and combinations of these conditions (Ilizarov 1992). The callotasis method originally described by Gavril Abromovich Ilizarov, using an external ring fixator to perform distraction osteogenesis (Ilizarov 1987), is a well known and a widely used procedure. However, in many cases the treatment time in the external fixator is long, although the increase in healing time is not linear with the lengthening distance of the callotasis zone, at least for moderate lengthening (Fischgrund et al. 1994). Moreover, this method is associated with many problems (Paley 1990, Velazquez et al. 1993, Kristiansen and Steen 1996, Choi et al. 1999). By using two lengthening zones instead of one, the

duration of treatment can be reduced. We report our experience with tibial lengthening by use of monofocal and bifocal osteotomies.

Patients and methods

During 1993–98, we lengthened 63 tibial segments in 49 patients (31 females) by using mono- or bifocal osteotomies. The indication for operation was constitutional shortness or various congenital or acquired deformities (Table 1). The average age was 16 (4–48) years.

Table 1. Indications for tibial lengthening in 49 patients

Diagnoses	Monofocal	Bifocal
Constitutional shortness	8	7
Achondroplasia/chondrodystrophy	1	12
Fibular hemimelia	5	5
Sequelae of fracture	7	0
Sequelae of osteomyelitis	0	3
Idiopathic leg length inequality	2	0
Hypoplasia tibiae	2	0
Epi-/metaphyseal dysplasia	0	2
Congenital malformation (dysmelia)	1	1
Ollier's disease	1	1
Congenital pseudarthrosis of the tibia	1	0
Blount's disease	1	0
Pes equino varus + hypoplasia	1	0
Tumor/benign	1	0
Osteogenesis imperfecta	0	1
Total	31	32

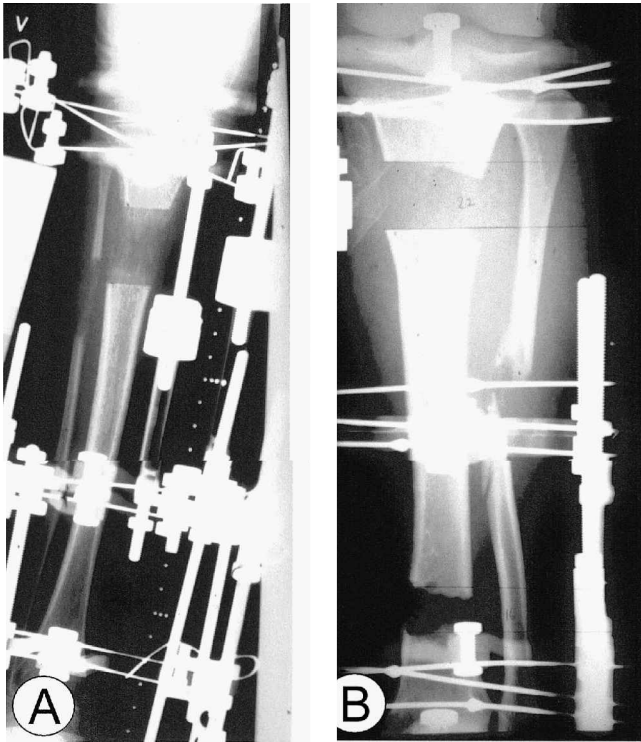


Figure 1. Tibial lengthening osteotomies by use of the Ilizarov external fixator; monofocally in the proximal metaphysis (A) and bifocally in both metaphyses (B).

In 31 tibiae, we performed monofocal lengthening with a metaphyseal osteotomy and application of the Ilizarov External Fixator (Smith & Nephew) (Figure 1a). When the preoperative planning showed deviation of the mechanical or anatomical axis, axial correction was done at the metaphyseal level (proximal: n 28; distal: n 3) according to the apex of the deformity (Paley et al. 1994). The frame, constructed of 3 rings, was mounted with 7 Kirschner wires (3 wires in the ring on the metaphyseal side of the osteotomy and 2 in each of the other rings). Bifocal lengthening was done simultaneously in the proximal and distal metaphyses in 32 tibiae (Figure 1b). The indications for bifocal osteotomies were lengthening requiring more than 5 cm or a bifocal deformity. The bifocal frames were constructed of 3 rings and each one was fixed with 3 wires.

Both in monofocal and bifocal lengthenings, the fibula was cut with an oblique mid-diaphyseal osteotomy and the segments were fixed to the tibia both proximally and distally.

The wires were tensioned to 1080 N (110 kilopounds). In the proximal tibial metaphysis, we used the Gigli saw osteotomy technique for monofocal and bifocal lengthenings (Paley and Tetsworth 1991). In the distal metaphysis, a corticotomy was performed with multiple cortical drillholes and the bone was then cut with a curved chisel (Figure 2) to protect the medullary cavity and vessels.

In all patients daily distraction lengthening was started on day 7 postoperatively and full weight bearing was allowed immediately. For lengthening only, distraction was planned at a rate of 1 mm/day (0.25 mm \times 4) in the monofocal osteotomy group and in the bifocal group at a rate of 1 mm/day (0.25 mm \times 4) proximally and 0.75 mm (0.25 mm \times 3) distally. In patients with additional axial deviations, lengthening and axial correction were started simultaneously with asymmetrical distraction. Oral antibiotics were

given if signs of pin track infection were noted. The distraction and consolidation process in the lengthening zone were checked regularly and complications recorded (Table 2). The external fixator was removed when symmetric callus and cortex on at least 3 sides were seen on biplanar radiographs. The lengthening index (LI) was calculated as months in the frame per cm lengthening (Paley 1990, Fischgrund et al. 1994).

Averages are expressed as arithmetic means and dispersion as 1 SD or range. Differences between mono- and bifocal lengthening osteotomies were evaluated with analysis of variance (ANOVA), a

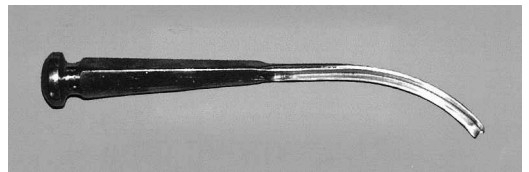


Figure 2. Specially designed curved chisel made in 1995 at the Ilizarov Clinic for Limb Lengthening and Reconstruction Surgery in Kurgan, Russia.

Table 2. Complications in 31 monofocal and 32 bifocal tibial lengthenings

	Monofocal	Bifocal
<i>Major complications</i>		
Joint contracture requiring surgery	4	8
Pseudarthrosis in the lengthening zone	1	4
Fracture after frame removal	1	3
Axial deformity after frame removal	1	1
Fracture outside fixator region	2	0
Skin necrosis in cast	1	0
Sum	10	16
<i>Minor complications</i>		
Joint contracture requiring physiotherapy	18	18
Deep pin tract infection	4	4
Transient peroneal nerve palsy	1	2
Premature consolidation	1	1
Sum	24	25
Total	34	41

value of $p < 0.05$ being considered statistically significant.

For graphical illustration, the data from both groups were put into a multiphase best fit model (SAS Institute Inc., statistical software program, Cary, NC). First, the changing point for each group was calculated and then the two curves were estimated using a maximum likelihood technique. The curve for the monofocal group was best fitted by a quadratic-linear function, while for the bifocal group, the linear-linear fit was more acceptable. However, to have the same type of functions, the quadratic-linear fit was used for both groups (Figure 3).

Results

Table 3 summarizes some of the data. In the monofocal group, the average lengthening was 4.8 (2.4–7.1) cm with an LI of 1.7 (0.9–4.4) months/cm (Table 4). In the bifocal group, the average lengthening was 7.4 (4.9–10) cm with an LI of 1.0 (0.7–2.1) months/cm. The difference in LI between the groups was statistically significant ($p < 0.001$).

The segments were divided into 3 subgroups regarding method and lengthening distance and the LI values were compared.

Group 1: Short lengthening < 49 mm (monofocal procedures only; n 14)

Group 2: Medium lengthening 49–71 mm (17 monofocal, 15 bifocal procedures; n 32)

Group 3: Long lengthening > 71 mm (bifocal procedures only; n 17)

With an increase in lengthening distance, the average LI showed a significant reduction from 2.2 in group 1 to 1.0 in group 3 (Table 4). In the subgroup representing both methods with overlapping lengthening distance intervals (group 2), the LI differed significantly from group 1 ($p < 0.001$), but not from group 3 ($p = 0.6$). In group 2, the LI of the segments operated on with bifocal technique was close to a significant difference from those with monofocal technique (1.4 vs 1.1; $p = 0.07$). However, with lengthening of 6 cm or more in group 2, the LI with bifocal lengthening was significantly lower than with monofocal lengthening ($p = 0.04$; Figure 3).

No differences in minor complications were found between the subgroups, such as transient ankle joint contracture and superficial pin track

Table 3. Data in 49 patients with tibial lengthening of 63 segments, mean (range)

	A	B	C	D	E	F	G	H
Monofocal	31	17.5 (4–48)	7.5 (3.7–13.8)	10/9	24/21	15/11	27/31	
Bifocal	32	14.7 (4–27)	8.6 (4.0–14.0)	16/14	25/21	13/12	29/32	
A. Type of osteotomy								
B. No. of segments								
C. Age (years)								
D. Time in fixator (months)								
E. No. of major complications/no. of segments								
F. No. of minor complications/no. of segments								
G. No. of additional operations/no. of segments								
H. No. of segments where planned lengthening and axial correction were achieved								

Table 4. Results of tibial lengthening (units) of 63 segments in 49 patients after 31 monofocal and 32 bifocal procedures. Mean SD (range)

Material	Mono-/ Bifocal	N	Lengthening	Index
<i>Tibial lengthening</i>	All	63	6.1 2.0 (2.4–10.0)	1.4 0.7 (0.7–4.4)
	M	31	4.8 1.6 (2.4–7.1)	1.7 0.8 (0.9–4.4)
	B	32	7.4 1.4 (4.9–10.0)	1.0 0.4 (0.7–2.1) ^a
<i>Subgroups</i>				
Short lengthening	M	14	3.2 0.9 (2.4–4.5)	2.2 0.9 (0.9–4.4) ^b
Medium lengthening	All	32	6.1 0.7 (4.9–7.1)	1.2 0.4 (0.7–2.1)
	M	17	6.1 0.7 (5.0–7.1)	1.4 0.4 (0.9–1.9)
	B	15	6.1 0.7 (4.9–7.0)	1.1 0.4 (0.7–2.1)
Long lengthening	B	17	8.6 0.6 (7.4–10.0)	1.0 0.3 (0.7–1.7)

^a Significantly different from monofocal index ($p < 0.001$)

^b Significantly different from medium and long lengthenings ($p < 0.001$)

infection. Although no patient with bifocal lengthening had to be hospitalized because of pain, distal distraction was terminated in all cases due to contractures or pain before final lengthening was achieved.

Complications requiring surgery were recorded as major and were commoner in the bifocal group (16 versus 10; Table 2)—i.e., especially the number of pseudarthroses and ankle joint contractures (4 and 8 versus 1 and 4 in the monofocal and bifocal groups, respectively).

Discussion

According to Reutov (2000), the bifocal lengthening osteotomy method was first proposed by Ilizarov in 1977, but only a few recent publications have reported results using this procedure (Fischgrund et al. 1994, Maffulli et al. 1996, Stanitski et al. 1996, Choi et al. 1999, Reutov 2000).

In our study, we found that the LI was significantly reduced in the bifocal osteotomy group, as noted by Fischgrund et al. (1994) and Maffulli et al. (1996). Fischgrund et al. (1994) concluded that double-level lengthening reduced the distraction-consolidation time when the total lengthening exceeded 4 cm, which accords with our findings. In our study, the LI in monofocal procedures seemed to stabilize at about 5 cm of lengthening (Figure 3), while the LI in bifocal procedures was usually more stable and at a significantly lower level.

Comparison of the LI between mono- and bifo-

Lengthening Index

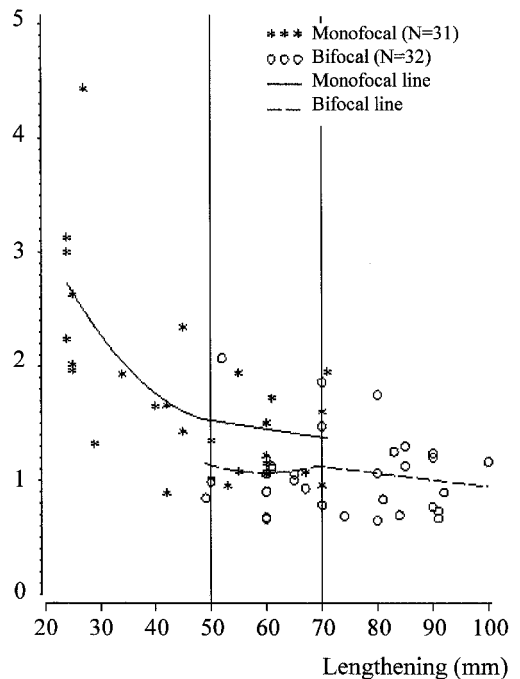


Figure 3. Lengthening index (months on the external frame/cm lengthening) in 31 monofocal and 32 bifocal lengthening osteotomies.

cal procedures in lengthening of the tibia should ideally be done only in patients with similar lengthening distances. In the subgroup including both methods with overlapping and comparable lengthening distances (group 2), the average difference in LI between mono- and bifocal osteotomies was 0.3 months/cm (1.4 vs 1.1 months/cm, respectively).

In lengthening of 6 cm or more, the difference was statistically significant. This may be because in total lengthening less than 6 cm, the healing callotasis consists of two separate and relatively short lengthening zones, each with an expected relatively high LI.

Both the achondroplastic and fracture sequelae diagnostic subgroups were unevenly distributed in mono- and bifocal lengthenings (Table 1). Age is an important factor in the time for distraction-consolidation (Fischgrund et al. 1994). Thus, age and diagnosis may be confounding variables in our study. However, the age difference (Table 3) between the groups was small and by excluding the subgroups from the material, bifocal osteotomies still have a significantly lower LI than monofocal procedures (1.6 vs 1.1; $p = 0.01$).

We had more major complications in segments operated on with bifocal technique as regards pseudarthrosis and persistent ankle joint contracture needing surgery. 4 of the 5 patients with delayed healing and pseudarthrosis were smokers, which may explain the nonunion in these cases (Cook et al. 1997). Consequently, smoking should be considered a contraindication in limb-lengthening procedures.

The increase in the number of ankle joint equinus contractures in the bifocal group may be caused by the higher total daily distraction rate of the tibial segment and soft tissues. We have recently reduced this problem by including the os calcaneus and forefoot in the frame prophylactically in bifocal lengthenings.

No patient needed hospitalization because of pain, but in almost all bifocal cases, the distraction rate had to be adequately reduced. We prefer to stop lengthening at one level instead of reducing the rate at both distraction zones, since slower lengthening may cause premature consolidation. This change in procedure from bifocal to monofocal lengthening must be done after axial malalignment has been corrected at the affected level. We chose distal osteotomy because of the close relation to the ankle joint.

We recommend bifocal osteotomies for longer lengthening (i.e., minimum 5-6 cm). In cases with axial deformities at two levels and lengthening less than 5 cm, we also prefer bifocal lengthening correction. However, in these cases, we stop the

distal distraction when axial correction has been achieved.

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