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ORIGINAL STUDY

A review of problems, obstacles and sequelae encountered during femoral lengthening : Uniplanar versus circular external fixator

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There is currently a consensus regarding the superiority of circular type external fixators over uniplanar fixators for lengthening of the tibia, but femoral lengthening is still subject to the surgeon's preference. This study compares the occurrence rates of significant problems, obstacles and sequelae between these two techniques. Fifty patients (29 male, 21 female), with a mean age of 20 years were assigned to a circular type fixator group (54 lengthening segments), whereas 60 patients (29 male, 31 female), with a mean age of 20 years were assigned to a uniplanar fixator group (67 lengthening segments). The incidence of knee stiffness was significantly higher in the circular external fixator group (0.31 per segment) compared to the uniplanar external fixator group (0.13 per segment) ($p < 0.05$). The incidence of pain during lengthening was higher in the circular external fixator group, and patient satisfaction was higher in the uniplanar external fixator group. We recommend the uniplanar external fixator as a preferable device for femoral lengthening.

Keywords : femoral lengthening ; unilateral fixator ; circular fixator.

INTRODUCTION

Codivilla (*3*) pioneered the lengthening of bone and soft tissues as early as 1904. Almost half of a century later, in 1951, the circular type external fixator (CEF) was invented by Ilizarov. The CEF was introduced to the western world in 1989 (*9*). The last century has seen the evolution of a number of limb lengthening techniques (*16*), each associated with a number of complications relating to both the learning curve and the method of application. There is some consensus regarding the superiority of the CEF over the uniplanar external fixator (UEF) for tibial lengthening (*6,11*), but the choice of external fixator for femoral lengthening is still a matter of debate and preference. A number of studies have highlighted the results of lower limb lengthening (*1,4,6,11,12,15*), but none of them, to our knowledge, have so compared the complications encountered during femoral lengthening using the circular and uniplanar fixators. The aim of this study is to evaluate the problems, obstacles and sequelae encountered during femoral lengthening using the CEF versus UEF.

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PATIENTS AND METHODS

This study was conducted at the Department of Orthopaedics and Traumatology of the University of Istanbul, Istanbul Medical School. The records of all patients having undergone femoral lengthening between September 1994 and January 2007 were retrospectively reviewed. All patients underwent surgery performed by one of the two senior authors (LE or MK). The LRS (Limb Reconstruction System, Orthofix® , Bussolengo, Italy) or a circular type external fixator was used during the lengthening. For circular fixation, we used a combination of full rings and arches, similar to the Italian modification. The choice of arch or ring depended on the body habitus of the patient. Distally, we mostly used 1 wire + 2 screws (1 posteromedial and 1 posterolateral) ; rarely 2 wires + 2 screws.

One hundred ten patients (58 male, 52 female) were split into two groups : 50 patients (29 male, 21 female) with 54 total lengthening segments belonging to group A (circular type external fixator) and 60 patients (29 male, 31 female) with 67 total lengthening segments belonging to group B (uniplanar external fixator). Lengthening was performed for congenital or acquired deformities with a minimum requirement of three centimeters of lengthening. For both groups, the mean age was 20 years. The inclusion criterion for the study was femoral lengthening, with the exception of segment transport cases. Patients with at least one year follow-up after removal of the external fixator were included. The exclusion criteria included incomplete data, follow-up of less than 12 months after the removal of the fixator, segment transport cases associated with tumour resection or resection of long osteomyelitis segments, lengthening over an intramedullary nail and cases of epiphyseal distraction. No patients were lost to follow-up. Complications were categorized as problems, obstacles and sequelae as described by Paley *et al* (*15*). The Paley difficulty score was recorded and analyzed for the patients. Frequency tables and statistical comparisons were calculated with SPSS 16 (SPSS Inc, USA). The distribution of categorical data including problems, obstacles, sequelae and total complication for both groups were compared with chi- square tests. A p value of less than 0.05 was considered statistically significant. Physical therapy was initiated immediately postoperatively. Knee range of motion exercises were performed as much as the distal ring of the circular frame permitted. Whenever possible, the posterior part of the distal ring was cut and removed in order to allow for more knee flexion.

Table I. — Patient demographics and comparison of lengthening parameters

	Group A - Circular fixator patients	Group B – Uniplanar fixator patients
Patient no	50	60
Segment no	54	67
M/F	29/21	29/31
Average age (years)	20	20
Congenital / others	16/38	37/30
Paley's difficulty score (average)	8	7
Lengthening (average, cm)	5.8	5.1
Lengthening index –days/cm. (average)	19.22	16.16
Lengthening aim achieved (% per segment)	79.62	88.05
Follow-up (average, months)	18.0	24.9

RESULTS

Comparison of patient demographics

Group A (circular fixator group) and Group B (uniplanar fixator group) were found to be similar in terms of patient demographics (table I). The various causes of shortening were classified as congenital or acquired ; they are identified in table II.

Pin tract infections

In group A, there were 13 cases of pin tract infections (0.24 per segment lengthened), of which only two were grade III. Both of these grade III infec-

Table II. — Details of aetiology
Diagnostic aetiologies corresponding to the number of segments lengthened

	Group A	Group B
Developmental dysplasia hip / coxa vara	2	2
Poliomyelitis	7	12
Post traumatic shortening with and without pseudarthrosis	16	13
Septic arthritis sequela	3	2
Proximal focal femoral deficiency with and without fibular hemimelia	7	13
Congenital femur shortening	5	9
Achondroplasia	2	13
Constitutional limb shortening	2	
Hip ankylosis with shortening	1	
Multiple epiphyseal dysplasia	2	
Avascular necrosis femur head	1	
Proximal femoral dysplasia	1	
Post tumour resection	1	1
Congenital pseudarthrosis femur	1	
Femur osteomyelitis sequela	3	1
Cerebral palsy		1

Table III. — Complications
Comparison of problems, obstacles and sequelae.

	Group A (Circular fixator)	Group B (Uniplanar fixator)
Problems	24	21
Obstacles	24	21
Sequelae	14	9
Total Complications	62	51
Complications per segment	1.14	0.76
Complications per segment (minus superficial pin infection)	0.94	0.55
Complications per segment (minus problems	0.70	0.44

Table IV. — Complications
Complications incidence per lengthened segment

	Group A (Circular fixator)	Group B (Uniplanar fixator)
Pin site infection	0.24	0.23
Fixator problems	0.07	0.0
Early consolidation	0.03	0.05
Plastic deformation	0.05	0.02
Joint dislocation	0.04	0.02
Joint contracture / stiffness	0.31	0.13
Delayed consolidation	0.11	0.04
Other	0.22	0.13

tions occurred in patients with shortening as a sequela of chronic osteomyelitis. The infected pin was removed in one patient, while the other patient required removal of the circular external fixator frame, debridement, parenteral antibiotherapy and conversion to a uniplanar fixator. All other cases responded to local and/or oral antibiotic therapy.

In Group B, there were 16 pin tract infections (0.23 per segment lengthened), of which two were grade III and required removal of Schanz screws and debridement ; one occurred in a patient with a sequela of osteomyelitis and the other in a patient with developmental dysplasia of the hip. Other cases were managed conservatively.

Joint stiffness/ decreased range of motion

In group A 17 segments (0.31 per segment) had problems with joint motion. Knee joint range of motion (ROM) was affected in 15 patients, isolated restriction of hip motion was encountered in two patients and both, hip and knee joint restriction existed in two patients.

Knee joint flexion deficits in three patients resulted in sequelae. One of these patients was lost during follow-up and sought treatment abroad. Upon return to our clinic after one year, this patient had significant deterioration of knee ROM and could not be completely rehabilitated. He had a final ROM from 10° to 60°. The second patient developed a grade III pin tract infection and poor

regenerate requiring removal of the CEF and application of a UEF with autologous bone grafting. Although the end result was satisfactory, knee joint ROM was restricted to 0-80°. The third patient started physical therapy, but was lost during follow-up with a final ROM of 0-70°. All other patients with knee and hip stiffness reached physiologic ROM values with physical therapy.

In group B, 9 segments exhibited a knee ROM lag (0.13 per segment) and there was no hip flexion deficit. Four patients recovered completely with physiotherapy and one patient was treated by supracondylar femoral extension osteotomy for resistant extension lag of 10° with flexion exceeding 120°. The other four patients were regarded as having sequelae and did not recover completely. One of these patients, who had a knee flexion deficit with ROM between 30 and 90°, had sustained a regenerate fracture, leading to delayed rehabilitation after cast application. The second patient also had a regenerate fracture during rehabilitation in the post fixator removal period. A uniplanar external fixator was applied to fix the fracture. Final knee ROM for this second patient was between 0-80° after physical therapy. The third patient had significant loss of knee ROM (0 –30°). The ROM for this patient improved with quadricepsplasty to 0-80°. The fourth patient developed posterior knee subluxation and despite brace treatment, could not regain motion beyond 10 to 70°.

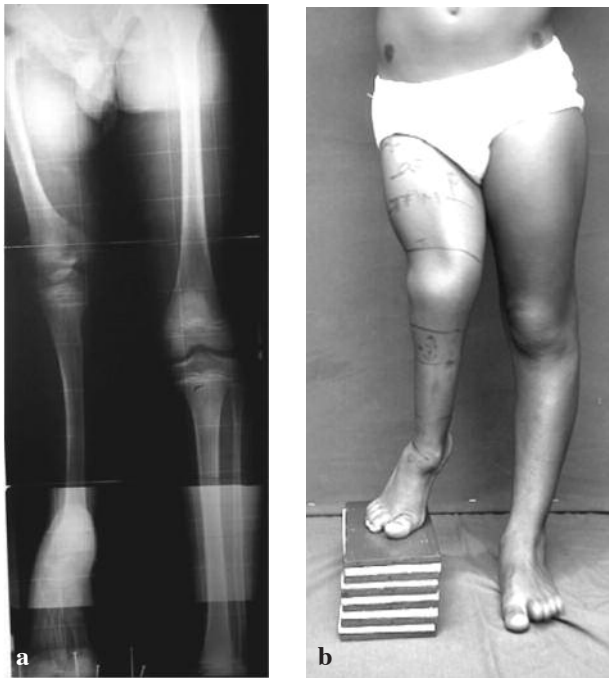

Fig. 1. — (a) Preoperative radiograph of a 13-year-old boy showing shortening and deformity associated with proximal focal femoral deficiency ; (b) Preoperative clinical picture of the same patient.

Joint dislocation/ subluxation

Group A included two cases of hip subluxation. The first case occurred in a 4-year-old boy with proximal focal femoral deficiency (PFFD) and required lengthening of 11cm with a Paley difficulty score of 13. After lengthening of four centimetres, superior migration of the femoral head was observed, requiring termination of lengthening and application of an abduction brace. The hip joint was reduced but the desired amount of lengthening could not be achieved. The second case was a 13-year-old boy, with PFFD and fibular hemimelia (fig 1a, b). The required lengthening was 18 centimeters. After lengthening of 15 centimeters, hip dislocation was observed. The patient was concomitantly treated for a varus deformity (corrected by valgus osteotomy) and a foot deformity (corrected with serial casting). A pelvic ring was applied for hip subluxation and gradual relocation was performed (fig 2). The final outcome was satisfactory although there was a remaining shortening of three centimeters requiring a shoe raise.

In group B, two patients, both lengthened for PFFD and fibular hemimelia, developed joint subluxations. The first patient was five years of age with a total required lengthening of 18 centimeters (fig 3). Nine centimeters of lengthening had previously been performed at the tibia. Eight centimetres of lengthening remained necessary. Both segments were lengthened simultaneously (fig 4). There was some knee joint incongruity before the start of lengthening. After lengthening of six centimeters at the femur, posterior knee joint subluxation was noted. The fixator was removed and a cast brace was applied. Despite a remaining

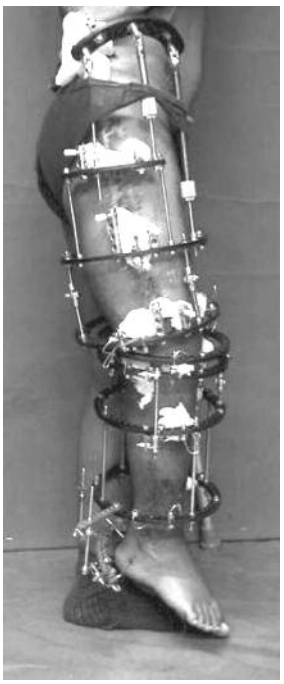

Fig. 2. — Postoperative clinical picture of the same patient. Note the bulk of the circular external fixator.

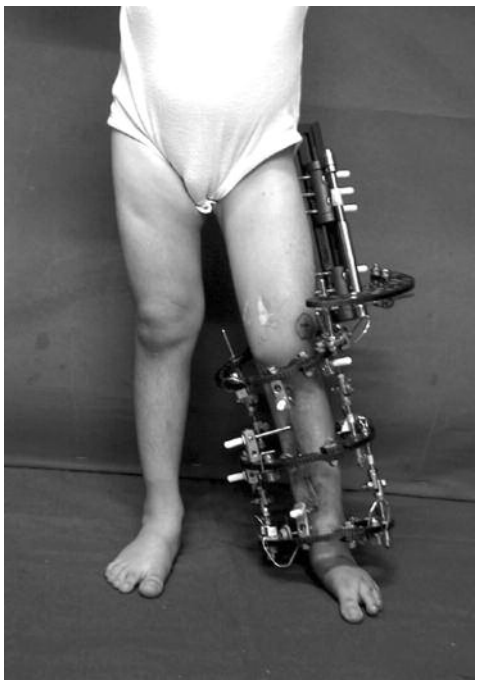

Fig. 4. — Clinical photograph showing simultaneous lengthening using an Ilizarov fixator at the tibia and a unilateral fixator over the femur. The unilateral fixator is markedly less bulky.

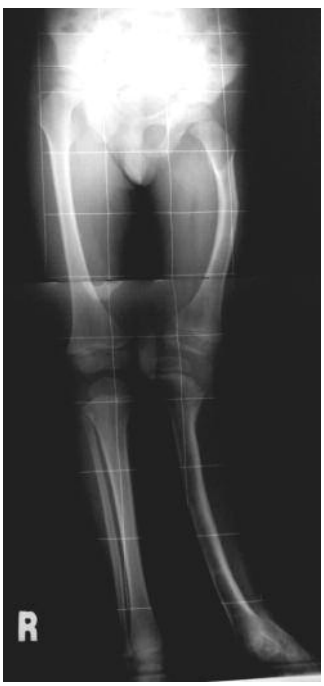

Fig. 3. — Preoperative orthoroentgenogram showing the previously lengthened tibia with deformity and residual shortening as well as shortening at the femur in a five-year-old child with proximal focal femoral deficiency and fibular hemimelia.

shortening of two centimetres the patient was satisfied and achieved a final knee ROM between 10 and 70°. The second patient was 12 years old and required lengthening of 14 centimeters. After lengthening of 9.5 centimeters, he developed hip subluxation and required application of a pelvic ring. The subluxation was reduced, but further lengthening was not achieved.

Other complications

Only one case of temporary neurapraxia, due to erroneous doubling of the lengthening rate by the patient, was noted in group A ; it resolved with compression of the regenerate by approximately 0.5 centimeter.

The circular ring broke in one patient following a fall. Most of the regenerate fractures were attributed to patient falls in the post fixator removal period although protective braces were applied. Similarly, the incidence of early consolidation, plastic deformation, delayed consolidation, defor-

mity and other related problems were low, were comparable in both groups and were not a consequence of fixator design.

Pain during lengthening as determined by a surgeon's assessment, (not on a visual analog scale), was found to be less in Group B. Correspondingly patient satisfaction was found to be much higher in Group B.

Total complication rate was statistically significantly higher in the CEF group than in the UEF group ($p = 0.009$). Among patients with a Paley difficulty score of more than 10, there was no statistically significant difference in the total complication rate in both groups. Although the incidences of various sequelae were higher in the CEF group, these differences were not statistically significant ($p = 0.08$).

DISCUSSION

The choice of external fixator remains a matter of debate for femoral lengthening. Recent interest in the use of techniques such as lengthening over nail (LON) (*6,11*) and intramedullary elongation nails (*5,13*) has decreased the interest in the debate over external fixators due to technical advantages and increased patient comfort associated with the above mentioned procedures. Importantly, expertise in the LON technique is limited to a few centers around the world and the motorized nails are still not easily available to patients in many underdeveloped countries for economic reasons. Additionally, children and patients with an active intramedullary infection are not candidates for the LON or motorized nail techniques. Therefore comparison of the significant complications of the use of circular and uniplanar fixators during femoral lengthening remains relevant and important. No studies have focused on this specific area of interest, although complications of lengthening have been cited. We have compared and analyzed the complications of femoral lengthening in the two patient groups, the circular type external fixator group (A), and the uniplanar external fixator group (B).

The incidence of total pin tract infections in groups A/B in our series is 0.24/0.23 per segment. Dahl *et al* (*4*) have reported various degrees of pin tract infection in all patients in their series whereas Paley (*15*) reported an incidence of 0.36 per segment. Deep infections in our series in groups A/B were 3.7/2.9 per segment. Dahl *et al* (*4*) and Paley (*15*) reported an incidence of 5-10 and 3.3% respectively. Although our values are comparable to published data, we predominantly observed deep infections in the osteomyelitis group. Therefore the deep infection complication can be attributed to this aetiology of shortening in our patients independent of the type of implant. To prevent deep infection, we recommend meticulous supervision of pin tracts during the early follow-up period. Rifampicin dressing for grade I and oral antibiotics plus rifampicin dressings for grade II infections should be started as soon as a problem is identified. Furthermore, any skin tenting at wire and Schanz screw insertion points should be released per- and post-operatively.

Knee ROM beyond 120° was considered full and between 90º-120º was considered functional. Extension deficit was considered if there was a lag equal to or above 10°. In general knee ROM decreased even before the start of lengthening in both groups and persisted in the majority of patients during the lengthening phase, consistent with the literature (*7,14*). Most of the patients recovered during the consolidation and post fixator removal phase in both groups. The significantly higher rate of knee stiffness in Group A (0.31 per segment) versus Group B (0.13 per segment) has changed our preference to use of the uniplanar fixator for femoral lengthening. We have observed a higher rate of significant loss of knee motion in congenital short femur cases compared to post-trauma or post-infection cases (*8,10*). Knee joint (one patient) and hip joint subluxations (three patients) were observed in our study. All of these cases belonged to the congenital group with pre-existing knee joint incongruity in one case. Long lengthening segments (equal or greater than 10 cm.) and Paley difficulty score of 10 or above were the other important common points in these cases. Therefore, this particular complication could be attributed to the pathology itself rather than the type of fixator used which is consistent with the literature (*2*). Patient satisfaction and pain during lengthening also favour the use of the UEF over the CEF.

The comparison of our study with studies by Paley (*15*) and Kocaoglu *et al* (*11*) reveals some interesting results. The incidence of total complications per segment and complications minus superficial pin infections in Group A (1.14/0.94) are nearly identical to the complications of lengthening resulting from the CEF method as described by Paley (1.23/0.9). On the other hand the corresponding rates of complications in Group B (0.76/0.44) are nearer to the complication rates observed for patients with LON, as reported by Kocaoglu *et al* (0.43/0.3).

Based on our experience we have changed our clinical practice over time. From 1994 until mid-1997, we exclusively used the circular type external fixator for femoral and tibial lengthening. Both types of fixators were used between 1997 and 2003. From 2003 onward, we have been using a uniplanar fixator for femoral lengthening, with satisfactory outcomes.

One should be cautious about loss of the overall alignment when switching to unilateral fixation for lengthening. In our series we did not encounter alignment loss related to lengthening with unilateral fixators. This can be attributed to the use of LRS-type stable unilateral fixators which also allow weight-bearing, similar to circular external fixators.

The evidence from our study favors the use of the uniplanar fixator for femoral lengthening. Attention to detail (*2*) can reduce the incidence of hip subluxations during lengthening of congenitally short femurs, independent of the type of fixator used. The incidence of knee stiffness, although low in the uniplanar fixator group, can be further reduced by the modification of Schanz screw placement as described by Simpson *et al* (*17*). The operating time for the placement of a uniplanar fixator is considerably less compared with the time required for the circular type external fixator. No preoperative frame assembly is required in the case of the former approach. The application of circular type external fixator in short stature patients with conical thighs can be very cumbersome and it is not well tolerated by patients. Based upon these findings we recommend use of the uniplanar external fixator for femoral lengthening, although we acknowledge the versatility of the circular type external fixators in selected cases.

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