



Knee mobility in femoral lengthening using Ilizarov's method

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Muscle contracture and joint stiffness are a major concern during limb lengthening using the Ilizarov method. The aim of this study was to detect factors that may influence the final loss of knee flexion.

We retrospectively studied knee movement in 32 patients undergoing femoral lengthening using the Ilizarov method.

The pattern of loss of knee movement showed a rapid fall in knee flexion during the latency period between operation and start of distraction, and the flexion loss continued during lengthening. There was a relationship between the worst knee range of motion achieved during lengthening and the final loss of knee flexion.

Intensive physical therapy is necessary in the latency period, because there is a rapid decrease in knee flexion, as well as during the whole lengthening procedure, in which flexion loss continues. Despite the flexion loss, patients finally regain good knee function after removal of the external fixator.

Keywords : femoral lengthening ; Ilizarov ; knee mobility.

ure (6,11,14). However, despite the more physiological nature of this method, the spectrum of potential complications remains the same with regard to the soft tissue, such as muscle contractures and joint stiffness (13,14). These complications may be related to the lengthening process itself and its effects on soft tissues, or to the transfixion of the soft tissues with pins and wires from the external fixation device (3,6,11).

Loss of knee flexion is a major problem during limb lengthening, because in order to give the muscle stimulus to grow, it is essential to obtain the best possible range of motion (ROM) (14).

The purpose of our study was to evaluate the knee flexion during and after femoral lengthening in our patient group. We also attempted to determine risk factors for loss of knee range of motion and its delayed recovery in patients who underwent a femoral lengthening. We especially focussed on a possible difference in flexion loss and recovery between traumatic and non traumatic causes of limb length discrepancy (LLD).

INTRODUCTION

The early techniques for limb lengthening such as the Wagner technique showed many complications related to the bone and the soft tissues. In comparison to these early techniques, the Ilizarov method has decreased the complications related to the healing of the bone, such as non-union, mal-union, deep infection and internal fixation fail-

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MATERIALS AND METHODS

Patient group

We retrospectively studied the files of 32 patients who underwent either isolated femoral lengthening or combined femoral and tibial lengthening using the Ilizarov method between 1995 and 2002. Eighteen of these patients required correction of an angular deformity in addition to lengthening.

There were 20 men and 12 women with a mean age at surgery of 29 years (range : 15 to 52). Only skeletally mature patients were included in our study. The aetiology of the limb length discrepancy was congenital in 10 patients, post infectious in 3 patients and posttraumatic in 19 patients. Mean follow-up time was 486 days.

Lengthening procedure

An Ilizarov frame was used with 4 Schanz half-pins proximally and 2 Schanz half-pins plus 2 Kirschner wires distally. After the Ilizarov frame was applied, a corticotomy was performed through a 2-cm incision. At the end of the operation, we checked that a passive knee flexion of 90° was possible. There was a latency period of 6 days before starting distraction at the rate of 0.25 mm 3 times a day. Sometimes the distraction rate was adjusted by the surgeon according to clinical conditions and radiological findings. Pin tract infections, leg alignment and callus formation were evaluated every two weeks. When lengthening had been completed, the external fixation device remained in place during consolidation of the bone. In 26 patients, the Ilizarov frame was reduced to a Monofix, a unilateral fixation system without any rings and with self-tapping screws and rods, as soon as corticalisation signs were visible on the radiographs. When full bone consolidation was completed, the frame was removed without further casting or bracing.

Physical therapy

Preoperatively the patients were evaluated for muscle strength, knee ROM, sensibility, limb length discrepancy, joint stability and general function. Immediately after the operation, the patients were positioned in an adjusted hospital bed with a pulley system that permitted them to perform passive flexion and extension in order to stretch the quadriceps and hamstrings (fig 1). During the hospital stay, patients received standard physical therapy twice a day. In the latency period, the therapy started with iso-



Fig. 1. — Pulley system that permits the patient to perform passive flexion and extension.

metric and active-assisted exercises. Weight bearing on the operated limb was also encouraged in this phase. During the lengthening and consolidation period, joint motion was exercised by means of mobilisation and stretching exercises. Gait rehabilitation was started the first or second postoperative day by attempting full weight bearing with 2 crutches. After removal of the fixation device, intensive physical rehabilitation was maintained to restore joint ROM, muscle strength, proprioception and gait pattern.

Data management

To allow comparisons to be made for patients who were lengthened at different rates, by different amounts and for different lengths of times, we considered the total time in the fixator as 100% and expressed the other data as a percentage of this total fixation time. Data for knee ROM preoperatively, pre-lengthening, at 50% of total fixation time and at the end of follow-up were collected. Maximum loss of knee flexion and final flexion loss were calculated. The rate of distraction was expressed as the lengthening index (days/cm), i.e. number of days of lengthening divided by the amount of length gained in cm. The time of fixation was expressed as the healing index (days/cm), i.e. total fixation time in days divided by amount of length gained in cm.

To detect factors associated with maximum flexion loss and final flexion loss, statistical analysis was performed on lengthening index, healing index, amount

Table I. — Clinical results

	Mean	Range	SD
Lengthening (cm)	4.1	1.8-9	1.85
Time in fixator (days)	222	110-436	81.7
Lengthening index (days/cm)	19.0	7.3-39.3	7.90
Healing index (days/cm)	62.1	21.3-174.4	31.3
ROM Preoperative (°)	123	90-145	13.6
ROM Prolengthening (°)	48.8	30-70	10.2
ROM 50% of fixation time (°)	42.0	5-95	19.3
ROM End result (°)	114	60-145	19.0
Maximum flexion loss (°)	96.3	60-125	16.7
Final flexion loss (°)	12.6	0-50	13.2

ROM : Range of Motion
SD : Standard Deviation.

lengthened, time in fixator, age and diagnosis (traumatic, congenital or infectious). Other variables were gender, smoking, combined axial correction, pin tract infections and combined femoral and tibial lengthening.

Statistical Analysis Software (version 8.0) was used for data analysis. Univariate correlations were obtained by the CORR procedure, using the Spearman correlation coefficients and the Pearson correlation coefficients. Student's t-tests were used to determine differences between different groups of patients while paired test statistics evaluated the time dependency.

RESULTS

For the 32 patients included in our study, the mean femoral lengthening was 4.1 cm (range : 1.8 to 9). The external fixator was left in place for an average of 222 days (range : 110 to 436). The mean lengthening index was 19 days/cm (range : 7.3 to 39.3), while the mean healing index was 62.1 days/cm (range : 21.3 to 174.4). Table I shows the results of clinical indices. Twenty of our 32 patients developed pin tract infections that needed treatment by oral antibiotics.

Pattern of knee flexion

The mean knee flexion preoperatively was 123° (range : 90° to 145°). A large amount of knee flexion was lost immediately after surgery and before starting the lengthening procedure (fig 1). The mean knee flexion 5 days postoperatively was 49° (range : 30° to 70°). During femoral lengthening,

the loss of knee flexion continued. The worst ROM was attained at the end of the distraction phase and was 26° (range : 10° to 45°). Despite the great loss in knee flexion, we never performed a tendon release of the quadriceps. After the lengthening procedure and removal of the fixator, knee flexion slowly recovered. The mean flexion at the end of follow-up was 114° (range : 60° to 145°). There was a significant difference ($p < 0.05$) between knee flexion preoperatively and at the end of follow-up. The mean final flexion loss was 12° (range : 0° to 50°). Eleven patients (34%) regained their preoperative ROM, 1 patient gained an extra 10° of knee flexion, but 20 patients (62.5%) still had an average loss of 20° knee flexion at 6 months after the removal of the apparatus (fig 2).

Risk factors

Patients who underwent simultaneously a correction of an axial deformity during femoral lengthening, lost more knee ROM than others who did not need a correction of the axis. Patients, who were distracted at a slower rate, also lost more knee flexion. There was no correlation found between maximum flexion loss and the aetiology of the LLD. Statistical analysis showed a positive correlation between maximum flexion loss and lengthening combined with axis correction ($r = + 0.48$), and lengthening index ($r = + 0.38$) (table II). We found a negative correlation between maximum loss of flexion and age ($r = - 0.32$).

Table II. — Correlation coefficients with maximum and final loss of knee range of motion

	Variable	r	p
Maximum Knee Flexion Loss	Combined axial correction	+ 0.48	0.006
	Lengthening index	+ 0.38	0.039
	Age	- 0.32	0.077
Final Knee Flexion Loss	Worst ROM	- 0.39	0.032
	Lengthening index	+ 0.38	0.039

ROM : Range of Motion

R : correlation coefficient.

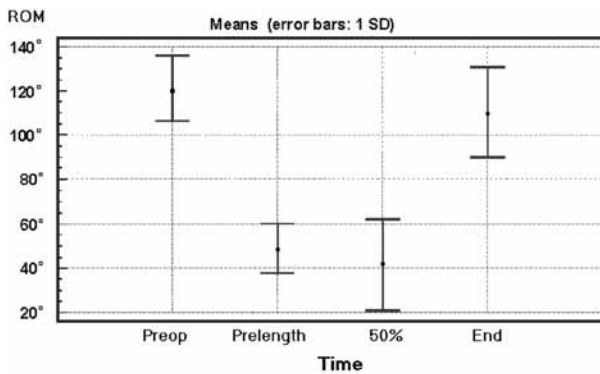


Fig. 2. — Evolution of knee flexion during femoral lengthening in males : Stages of measurement : preoperative, prelengthening, at 50% of total fixation time, end result.

When we looked for factors influencing the recovery of the loss of knee flexion, statistical analysis showed no correlation between final flexion loss and aetiology of LLD, nor did we find a relationship between maximum flexion loss and final flexion loss. We found a positive correlation between final flexion loss and lengthening index ($r = + 0.38$). A negative correlation was found between final flexion loss and worst ROM ($r = - 0.39$) and knee flexion half-way the lengthening procedure ($r = - 0.38$).

DISCUSSION

Soft tissue complications, such as muscle contractures and joint stiffness remain important problems during femoral lengthening (1,3-6,11,13-16,19, 21).

Our study found a biphasic pattern of loss of knee flexion during femoral lengthening by the

Ilizarov method. First there was a rapid decrease in knee flexion, directly after surgery and before starting the distraction procedure. Secondly, there was a further loss of knee flexion during the lengthening procedure itself. There are multiple factors which all contribute to the early loss of knee flexion during the latency period. Transfixation of muscle or tendon by the pins and wires of the Ilizarov apparatus may restrict joint motion (3,4,6,7,11,13,14,20,21). In 2002 Simpson and Barker (14) compared two groups of 10 children during femoral lengthening. In one group they used a standard method for pin placement and in the second group they used a modified technique that checked more carefully for tensioning and tethering of the soft tissues. Careful pin placement can significantly improve the knee flexion of motion, both in the latency period and during lengthening (1,14). Other explanations for this early loss of movement are physical constraints imposed by the fixator, apprehension about moving, poor psychological acceptance and last but not least insufficient analgesia after the surgical intervention (1,3,6,11,14). Our experience taught us that patients still under general anaesthesia had knee flexion of 90°, which was rapidly lost in the first hours postoperatively.

The second phase of loss of knee motion during femoral lengthening itself is the result of the tension generated on the muscle due to distraction (3,8,13). The optimal rate of distraction histogenesis for musculotendinous, vascular and neurological tissues is slower than those shown to lead to the best osteogenesis (2,5,9,15,19). In limb lengthening with the Ilizarov method, the rate of distraction that is optimal for new bone formation is used. Histological studies found that during limb distrac-

tion the muscle fibres lengthen by addition of new serial sarcomeres (15). However, in spite of this apparent adaptation to the new functional length, there is a loss of range of motion, due to the increased passive tension exerted by the distracted muscles. These muscles show a significant increase in collagen volume fraction in the perimysium and endomysium (15,19). This indicates that during prolonged stretching the connective tissue elements remodel less readily than the contractile component, with the subsequent fibrosis and loss of range of movement in the distracted limb.

Our data show a relationship between maximum flexion loss and a combined correction of an axial deformity during femoral lengthening. Patients, who have an axial deformity that is being corrected, lose more knee flexion. This may be explained by the fact that the muscle in such a case is not stretched in a constant direction. Stretching the muscle following an axis that alternates in an axial plane may cause a less efficient stimulus to grow. On the other hand, patients with an axial deformity already had a significantly ($p = 0,002$) worse knee motion preoperatively in comparison with patients without axial deformity.

The age of the patient during the procedure was also a factor that influenced the maximum flexion loss. Young individuals lost more knee flexion than older patients. Barker *et al* (3) found the same correlation and explained this by the fact that most of the children received surgery for congenital deformities, which are known to have a greater complication rate. In children, lengthening was also producing a genuine increase in the limb length, while in adults normal length was restored (3).

In contrast with the last author, we did not find a negative, but rather a positive correlation between maximum flexion loss and lengthening index. Our patients who were distracted at a slower rate lost more knee flexion. We have no clear explanation for this. We can only confirm that at present the rate of distraction in our clinical practice is determined mostly by factors which enhance osteogenesis. Patients who were elongated at a slower rate also had a greater final flexion loss of knee movement 6 months after removal of the apparatus.

Another factor influencing the final loss of knee flexion was the worst knee flexion during lengthening. Patients finally lost more knee motion, if their ROM during the lengthening procedure diminished more severely. According to Ilizarov, one of the biological and clinical principles important to the proper formation of new bone is normal physiological use of the elongating limb in a fixator that is permitting an adequate range of joint motion (7). Patients undergoing treatment with the Ilizarov external fixator, need intensive physical therapy to maintain some joint motion throughout the procedure (3,5). Once again this shows that intensive physical therapy is a key to success with the Ilizarov limb lengthening procedure. It is absolutely necessary to obtain the best possible ROM during lengthening in order to stretch the muscle and give the muscle an efficient stimulus to grow.

Our data fail to show any relationship between the aetiology of LLD and loss or recovery of knee flexion. However, Maffuli *et al* (11) found a significant trend for patients with a congenital LLD to lose ROM more quickly, and to regain the original ROM at a slower pace. According to the same author, the External Fixation index, also called the healing index, was significantly lower in posttraumatic and post infectious LLD than in congenital conditions, with no significant difference between posttraumatic and post infectious patients (10). Aaron *et al* (1) found a large number of complications in patients who had a congenital short femur, due to the presence of associated anomalies and soft tissues that were relatively resistant to lengthening.

In conclusion, we found a rapid decrease in knee flexion in the prelengthening period, and the flexion loss continued during lengthening. There was an association between the worst ROM achieved during lengthening and the final loss of knee flexion. These findings stress the need for obtaining the best possible ROM during the whole lengthening procedure. A surgical technique with little tensioning and tethering of the soft tissues and intensive physical therapy from the beginning till the end of the limb lengthening procedure are the keys for a successful treatment.

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