

Femoral Lengthening using the Ilizarov Technique

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ABSTRACT

The Ilizarov method allows the surgeon to perform extended lengthening of both congenital and acquired short limbs. The technique can be difficult, time consuming and is associated with many complications. Generally, the number of complications and failures of lengthenings increases in proportion to the length of the distraction and the severity of the preoperative problems. The rate of major complications decreases substantially as the experience of the surgeon increases.

Alargamiento Femoral Mediante la Técnica de Ilizarov

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RESUMEN

El método de Ilizarov permite al cirujano realizar alargamientos extensos tanto en el caso de miembros cortos congénitos como adquiridos, pero la técnica puede ser difícil, y requerir mucho tiempo, además de hallarse asociada con numerosas complicaciones. Por lo general, el número de complicaciones y fallos en los alargamientos, aumenta en proporción con la longitud de la distracción y la severidad de los problemas preoperatorios. La tasa de complicaciones mayores disminuye sustancialmente a medida que aumenta la experiencia del cirujano.

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INTRODUCTION

Limb-length discrepancy is not an uncommon problem in children. The most common causes are congenital hypoplasia, skeletal dysplasia (1) or growth arrest as a result of trauma or infection. Discrepancies of less than 5 centimetre (cm) are conventionally treated by a shoe lift, epiphysiodesis or femoral shortening. Most patients are reluctant to wear a lift greater than 2 cm. Discrepancies in excess of 5 cm may warrant limb lengthening. Codivilla documented the first femoral lengthening in 1905 (2). He described the use of an osteotomy of the cortex and immediate application of a traction force to a calcaneal pin. This technique was subsequently modified by Abbott (3) and Anderson (4). In the 1970s, Wagner (5) popularized his technique using a uniplanar external fixator for limb lengthening. These methods, although effective, were associated with an unacceptably high rate of complications (6). The common complications included infection, refracture, hypertension, compartment syndrome, nerve palsy and joint subluxation and dislocation.

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With the introduction of more physiologic methods of lengthening pioneered by Ilizarov and based on the biology of bone and soft-tissue regeneration under the conditions of tension stress, the bone-healing problems have become less common and less difficult to manage and the goals of treatment are usually achieved (7, 8).

Four cases of femoral lengthening and their complications are reported along with a review of the literature.

CASE 1

An 11-year old female presented to the Orthopaedic Service, University Hospital of the West Indies (UHWI), with 10 cm shortening in the left femur secondary to a physal injury of the distal left femur. The preassembled Ilizarov frame was applied and connected to the femur with wires and half-pins. The rings and arches were connected to each other with rods. Fluoroscopy was used to ensure accurate placement of the wires and half-pins. A longitudinal incision was made along the lateral aspect of the distal left femur and a 2 cm longitudinal incision was then made in the periosteum which was elevated to allow multiple cortical drill holes in the metaphysis. These holes were connected with an osteotome, great care being taken not to damage the periosteum. Two-thirds of the circumference of the cortex was transected with an osteotome and the remainder of the osteotomy was performed with osteoclasis by twisting the fragments in opposite directions using the frame. The connecting rods were then

tightened to the rings and arches. The osteotomy site was compressed by turning the nuts or 'clickers' in a counter clockwise manner. Betadine soaked squares of gauze were placed around the wires and half-pins. Distraction was commenced seven days later, and the rate of distraction was 0.25 mm every six hours. Physical therapy was started immediately and continued throughout the lengthening period to maintain ranges of motion of the hip and knee. The patient and parent were shown how to turn the nuts prior to the child being discharged from hospital. The patient was discharged after 14 days with a prescription for oral antibiotics which were to be taken only if a pin site infection developed. The signs and symptoms of the pin site infection were explained to the patient and parent. Daily cleaning of the pin sites with cotton swabs soaked in normal saline to remove all crusts was recommended. Weekly follow-up with plain radiographs to ensure good quality of the regenerate bone was maintained for the first month and then three weekly until distraction was complete (Fig. 1). This patient developed

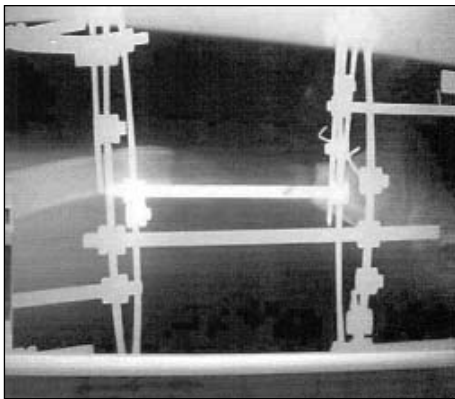


Fig. 1: Femoral lengthening using the Ilizarov frame. Good regenerate bone is present in the distraction gap.

multiple pin site infections which resolved in a few days with oral antibiotics. No wires or pins had to be removed or changed. After 6 cm of lengthening, the patient began experiencing severe pain on range of motion of the knee. Plain radiographs showed mild subluxation of the knee joint. The Ilizarov frame was extended across the knee joint to correct the subluxation and prevent compression of the articular cartilage. After the required length was achieved (distraction phase), the frame was maintained until complete consolidation occurred. The total time in the frame was calculated at approximately one month for each cm lengthened in children. This patient's frame was removed after twelve months, and at that time the knee was found to be ankylosed at 0° of extension. Intensive physical therapy failed to improve the range of motion of the knee. A Judet Quadricepsplasty was then performed. At nine months follow-up, there was 90° of active flexion and no extension lag (Fig. 2).



Fig. 2: Patient with equal lower limb lengths following femoral lengthening.

CASE 2

A 17-year old female presented to the Orthopaedic Service, UHWI, with 4 cm shortening in the right femur secondary to a femoral fracture at age eight years (Fig. 3). The patient



Fig. 3: Posterior view of the lower limbs showing inequality of limb lengths.

chose to undergo femoral lengthening rather than femoral shortening on the unaffected limb along with a shoe lift. The osteotomy was performed in the distal femoral metaphysis. The Ilizarov fixator was applied on October 2, 2002. The principles for optimization of the regenerate bone were followed: low energy osteotomy, stable external fixation, latency period of ten days, distraction rate of 0.25 mm four times per day and a period of consolidation. A programme of physical therapy was instituted on the first post-operative day and maintained throughout the period of distraction and consolidation. Following removal of the fixator on February 14, 2003, physical therapy was continued with restoration of full flexion of the knee (Figs. 4, 5).



Fig. 4: Standing view showing equal limb lengths following femoral lengthening.



Fig. 5: Standing view with right knee in maximum flexion following femoral lengthening.

CASE 3

A 17-year old male presented to the Orthopaedic Service, UHWI, with a limb length discrepancy of 13 cm, marked limitation in knee motion (0° to 30°) and severe osteoarthritic changes in the knee. The limb length discrepancy was entirely in the left femur. At birth, there was shortening and varus angulation of the left femur with hypoplasia of the medial femoral condyle. The hospital records revealed that at age six years, a femoral osteotomy was performed to correct the angulation. An epiphyseodesis of the right knee was performed; the date of which is uncertain. The Ilizarov frame was applied on May 17, 2004 and distraction commenced ten days later at a rate of 0.25 mm every six hours. The osteotomy was performed in the distal femoral metaphysis. Poor

regenerate bone was noted at follow-up in July 2004. The rate of distraction was reduced to 0.25 mm daily for one week. Follow-up plain radiographs revealed no improvement in the quality of the regenerate bone. Distraction was discontinued and the distraction gap was compressed at a rate of 0.25 mm daily for two weeks. The quality of the regenerate bone improved and lengthening was resumed at a rate of 0.25 mm every six hours. Distraction was discontinued once equal limb lengths were achieved. The frame was removed after complete consolidation had occurred.

CASE 4

A 14-year old female presented to the Orthopaedic Service, UHWI, with a 15.5 cm femoral shortening in the right lower limb and congenital coxa vara of the right hip. Prior to application of the Ilizarov frame, plain radiographs of the right hip in abduction and adduction were taken to assess the amount of coverage of the femoral head and the stability of the hip joint. The CE angle of Wiberg of the right hip measured 15° . The frame was extended across the knee to prevent joint compression and subluxation. The osteotomy was performed in the distal femoral metaphysis. After 8 cm of femoral lengthening, the right hip subluxed. Distraction was immediately discontinued and the distraction gap compressed sufficiently to allow reduction of the hip joint. No further lengthening was attempted at this time. The present length of the regenerate bone is 5 cm and this will be allowed to consolidate, after which the frame will be removed. An osteotomy to provide better coverage for the right hip will be undertaken before performing another lengthening procedure on the femur.

DISCUSSION

The Ilizarov method allows the surgeon to perform complex and extended lengthening of both congenital and acquired short limbs, but the technique can be difficult, time consuming and is associated with many complications (9, 10). Ilizarov coined the term distraction osteogenesis to describe the induction of new-bone formation between osseous surfaces that are gradually pulled apart (11). With the use of modular ring external fixators and transosseous wires attached to the rings and the tension to stabilize the bone fragments, he introduced the concept of induction of local bone formation with a minimally invasive procedure (12). According to Ilizarov, the principles for optimization of good regenerate bone are: maximum preservation of marrow and periosteal blood supply, stable external fixation preventing torsion and bending yet allowing axial micromotion, latency period of seven days to fourteen days, incremental distraction of 0.25 mm four times per day and a period of consolidation necessary to allow the regenerate bone to ossify. Total time in the fixator can be estimated to be approximately one month for each cm lengthened in children and two months or longer per cm lengthened in adults. Many authors have

indicated that the periosteum is the major contributor to osteogenesis during distraction (11, 13, 14). Consequently, methods of bone separation that disrupt the periosteum, such as widely displaced osteotomies, can result in decreased osteogenesis (15).

The impact of lengthening on bone and soft tissues is probably more important than the choice of external fixator or the precise method of lengthening used. Ilizarov studied the effect of stretching on bone and soft tissue (7, 8) and termed the tissue response to gradual stretching, the tension-stress effect. In general, tension created by gradual distraction stimulated the formation of new bone, skin, blood vessels, peripheral nerves and muscle. A continuous distraction rate of 1 millimetre (mm) per day in increments of 0.25 mm every six hours leads to maximal new bone formation in the distraction gap. Histologic examination of the distraction gap in animals showed the development of dense, longitudinally arranged collagen bundles with no cartilaginous tissue evident. This is referred to as primary intramembranous ossification (16, 17).

Although new-bone formation is the most identifiable and dramatic effect of lengthening, it is the impact of lengthening on the soft tissue and articular surfaces that dictates the ultimate function of the lengthened limb. The response of muscle to gradual lengthening has also been studied. Sun *et al* (18) observed myofibrillogenesis, primarily near the myotendinous junction, while Matano *et al* (19) reported that the average sarcomere length increased initially with stretch but then decreased. Clinically, the threshold of soft tissue tolerance to gradual lengthening is often limited to 15% to 20% of the original length of the lower limb segment. Lengthenings greater than this result in substantial histopathological changes in the muscle (20, 21).

The reaction of blood vessels and nerves to the continuously increasing traction during callus distraction has been investigated by Fink *et al* (22), Battiston *et al* (23) and Ippolito *et al* (24). The results of their study indicate that the vessels possess a tolerance for the continuous traction during extremity lengthening. Various mechanisms may be responsible for this. Due to the sliding of the vessels within their surrounding tissue, the traction should at first lead only to a straightening of the curved blood vessels during distraction. The high viscoelastic properties of blood vessels enable them to be lengthened considerably without suffering structural damage. A further explanation for the excellent adaptation of the blood vessels to the distraction could be the small distraction steps. Nerves, arteries and veins showed histological evidence of temporary degenerative changes but these disappeared two months after lengthening.

Articular cartilage appears to incur negative effect from lengthening of adjacent bones. Stanitski *et al* (25) reported gross cartilage fibrillation and loss of proteoglycan staining in the knees of dogs that had 30% femoral lengthening. However, the authors noted that when the apparatus was extended across the knee, these changes would

be ameliorated, presumably by preventing joint compression during lengthening.

Limb-length discrepancy due to paediatric hip disorders is a common problem in paediatric orthopaedics and femoral lengthening is increasingly being used to treat these conditions. Hip dislocation or subluxation can be a serious complication of limb lengthening procedures (5, 22). Suzuki *et al* (27) showed that hip deterioration during femoral lengthening occurred in the hips that had poor acetabular coverage due to hip disease or disease related to the hip joint. The deterioration was closely related to the preoperative angle of Wiberg (CE). When the CE angle was greater than 20°, the hip showed no deterioration. In contrast, when the CE angle was less than 20°, hip displacement was likely. The authors recommend an innominate osteotomy prior to lengthening in those hips with a CE angle less than 20°.

Independent of the methods used and the aetiology of the problem to be treated, limb-lengthening is routinely associated with a plethora of complications. Complications can involve the pin tracks, bones, joints, neurovascular structures and mental status (28). Local soft tissue irritation and low-grade pin site infection are common with external fixation. In most patients, irritation and infection can be managed by careful avoidance of tension on the soft tissue at the time of wire and half-pin placement, compressive dressings around the pin sites where they are subjected to movement during therapy and intermittent oral antibiotics. Although rare, deep infection or ring sequestra should be suspected, when there is persistent infection or drainage after wire or half-pin removal. During the lengthening procedure, motion of the joint may be temporarily or permanently lost as a result of muscle contracture, arthrofibrosis, damage to the cartilage, or joint subluxation. Vigorous physical therapy with the goal of maintaining motion must be instituted. Extension of the frame across the joint will prevent subluxation in the at-risk joint.

Nerve or major vessel injury can occur peri-operatively by direct injury during fixation or in association with post-operative compartment syndrome. Injury can occur secondarily during lengthening because of excessive distraction or impingement of nerves or vessels against wires or half-pins.

Osseous complications may involve premature or delayed consolidation, axial deviation, late bending or fracture. Poor regenerate bone may lead to a prolonged time in the frame and creates a higher risk of regenerate bone fracture or bending. Poor regenerate bone may result from too short a latency period, too rapid distraction or poor local blood supply (29).

Paediatric patients often have sleep disturbance, trouble maintaining school work and may lose weight during the active phase of lengthening (29). Preoperative counselling to families is helpful in minimizing these problems.

Generally, the number of complications and failures of lengthening increase in proportion to the length of the distraction and the severity of the preoperative problems (10,

30). The rate of major complications decreased substantially as the experience of the surgeon increased (10).

The use of the Ilizarov apparatus has expanded the surgeon's ability to correct severe or complex angular deformity and to equalize significant limb length discrepancy. However, this technique is challenging for patients, their families and the surgeon. Because it is a complex solution, its use should be limited to reconstructive problems for which simpler alternatives are inadequate. The surgeon should be thoroughly versed in this treatment method and the patient and family counselled before undertaking the procedure.

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