Managing Flexion Knee Deformity Using a Circular Frame

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Abstract Knee flexion deformity can cause marked physical disability. Acute correction, whether nonoperative or operative, may lead to serious complications. We treated 50 patients (71 knees) between 1994 and 2002 with the Ilizarov external fixator. The deformity was gradually corrected using Ilizarov principles. Of the 50 patients, 29 were affected unilaterally and 21 bilaterally. In 15 patients, there were associated deformities. In no patient did we surgically release soft tissues; in two patients with arthrodesed or congenitally fused knees, we performed osteotomy before distraction. All patients were assessed clinically and radiographically. We assessed knee flexion angle, range of motion, stability, presence of pain, and healing index. After a minimum followup of 1 year (mean 3.7 years; range, 1–8 years), 18 of 20 of the preoperatively nonambulatory patients having bilateral surgery could walk at last followup. Complications included pin tract infection in all patients, knee subluxation in three patients, and fracture related to treatment in seven patients. We believe gradual correction using a circular frame an effective

method to treat flexion knee contractures. In patients with bilateral deformities, improvement in functional activity may be expected in most patients.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Major knee flexion deformity is disabling and acute correction of flexion knee contracture with soft tissue release, osteotomy, or both may lead to serious complications [14]. Soft tissue release may be complicated by peroneal palsy, knee subluxation, hyperextension, skin necrosis, and recurrence [12]. The treatment often depends on the degree of deformity [19]. With multiple pterygium syndrome, these authors recommend physiotherapy, splinting, soft tissue release, serial casting, arthrodesis in extension, or amputation to be performed according to the degree of knee flexion deformity: less than 25°, 25° to 90°, and more than 90°. However, one study suggests there is no correlation between neurovascular complications and the degree of preoperative contracture or patient age [2]. It seems the development of complications after acute correction is unpredictable. Ilizarov's law of tension stress [16] has been advocated using the circular external fixator to treat these sorts of deformities, as gradual controlled traction on living tissues creates stresses that stimulate regrowth of these tissues.

Gradual correction of the deformity has been reported previously using various external fixators [6, 12, 23]. Several authors have used an Ilizarov circular fixator [6], a monolateral fixator [12], or hinged distraction apparatus [23]. Two of these authors reported associated procedures

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including hamstring release [12] or supracondylar osteotomy and tenotomy of the medial and lateral hamstrings [6], although Volkov and Oganessian [23] used only distraction without operative procedures. Given the variability of the conditions and joints for which the procedures have been used and the variability of techniques, it is difficult to compare results.

Using a consistent approach, we determined the degree of improvement of the flexion contractures and the arcs of motion, the ability of the approach to convert nonambulatory to ambulatory patients, the rate of recurrence of flexion deformities, and the complications.

Materials and Methods

We retrospectively reviewed all 69 patients with fixed flexion knee deformity of 25° seen between 1994 and 2002. We excluded 13 patients with cerebral palsy and myelomeningocele. This left 56 patients, all of whom were treated with the Ilizarov external fixator. Of the 56 treated patients, six additional patients were excluded due to inadequate followup data. Of these 50, there were 28 female and 22 male patients (Table 1). The average age at operation was 15.5 years (range, 2–30 years). Twenty-nine patients had unilateral deformities and 21 had bilateral. Twenty of the 21 with bilateral deformities were nonambulatory. Eight patients had polio residuals (two with bilateral and six with unilateral deformities), two of whom were nonambulatory with almost flail limbs. Two patients had lumbosacral agenesis. Five patients had preoperative knee subluxation. Thirty-nine patients had previous surgery for their flexion contractures in the form of posterior soft tissue release, supracondylar femoral recurvatum

osteotomy, posterior release and gradual correction by external fixator, and posterior capsulotomy. The number of previous operations ranged from one to eight (average, three). In 15 patients there were associated deformities: seven with club feet, five with lower-limb inequalities, and three with angular deformities. Of the 50 patients, 20 were nonambulatory (wheelchair or crawling). Patients were followed a minimum of 1 year (mean, 3.7 years; range, 1–8 years).

Osteotomy alone was performed in a patient with a previously arthrodesed knee and congenital fusion in another patient. Lengthening was performed following osteotomy in these two patients and following corticotomy in the distal femur in 4 patients with femoral shortening with application of extra proximal arch (90° arch) and 2 Schanz screws, to increase the stability of the frame. Femoral lengthening with correction of the knee flexion deformity were performed concomitantly in those cases. Distraction from the corticotomy site started one week after application at a rate of 1 mm per day. We did not fix the physis as a routine. The tibial construct consisted of one and a half or two rings applied to the tibia and each was fixed with two or three wires (1.5- or 1.8-mm K wires according to the size of the bone). The femoral construct consisted of either one and a half rings or one and a 5/8 ring. The half ring or 5/8-ring was fixed by two or three K wires to the metaphyseal part of the lower end of the femur. In our early cases the ring was fixed to diaphysis by two or three half pins or Schanz screws (2, 3, 4, or 5 mm). However, due to the development of fractures in relation to the most proximal half pin, we began using a single K wire directed from posterolateral to anteromedial instead. In cases of popliteal webbing, we used two plates to connect the proximal two femoral half rings to create an oval rather than a ring to prevent pressure of the ring on the web by the lower part of the frame. The circular fixator was applied vertical to the femur and tibia. The femoral frame and tibial frame were linked with two uniplane hinges situated virtually slightly anterior to the center of joint rotation. The position of the hinges was changed during followup visits based on the relation between femoral condyles and upper tibia. Distraction was applied posteriorly using one or two distraction rods. The position of the hinges was modified if there was subluxation in order to correct it during distraction (Fig. 1). Foot deformities were corrected in 11 of our patients by extending the frame to the heel and forefoot and applying distraction [15]. The average operative time was 70 minutes (range, 40–130 minutes).

Patients were discharged from the hospital the same day or 1 day postoperatively. Prophylactic parenteral antibiotics were given for 3 days postoperatively in the form of third-generation cephalosporins. At the first visit 3 days

Table 1. Etiology of the deformity

Etiology	Number of patients	Unilateral	Bilateral	Total knees
Arthrogryposis multiplex congenita	16	—	16	32
Lumbosacral agenesis	2	—	2	4
Tibial hemimelia	3	3	—	3
Multiple pterygium syndrome	1	—	1	2
Congenital short femur	5	5	—	5
Arthrodesed knee in flexion	2	2	—	2
Poliomyelitis	8	6	2	10
Posttraumatic	10	10	—	10
Fibular hemimelia	3	3	—	3
Total	50	29	21	71

Fig. 1A–F (A) AP radiograph of 17 years old boy with left knee flexion deformity and subluxation. (B) Lateral radiograph showing 90 degrees flexion deformity and subluxation. (C) AP radiograph after fixator application and distraction. (D) Lateral radiograph during correction of the deformity. (E) AP radiograph after fixator removal. (F) Lateral radiograph at last follow up showing correction of the deformity and reduction of the dislocation.

postoperatively we began applying a local antiseptic two times per day for pin care. Analgesics were regularly given for 1 week postoperatively. The patients were examined every week until correction was achieved, then every other week until fixator removal. Clinical examination was performed for the signs of pin tract infection, peripheral circulation and sensation, and measurement of the knee flexion angle by goniometer. Roentgenograms were obtained at each every other week visit to check for subluxation and degree of joint distraction, as well as rarefaction due to pin loosening.

We used the rule of similar triangles or the rule of concentric circles [13] to determine the rate of distraction. Usually the neurovascular bundle was distracted faster than the joint, especially in cases of webbing as it lies

more posteriorly. The rate was modified according to the patient's compliance or the development of numbness. We continued the distraction until overcorrection of approximately 5° was achieved and then began loosening the hinges and mobilizing the joint for a period of 1 month to allow for active and passive movement using the distractors. With patients early in the series, we observed the arc of knee motion did not change substantially despite deformity correction and functional improvement. Therefore, in the last eight patients, after reaching the point of 5° overcorrection, we flexed the knee gradually and extended it gradually using the same rate each direction (incrementally flexing or extending 5–10 mm every 6 hours daily, guided by patient tolerance) but at a faster rate than the original rate of distraction

using the frame (passive correction). The time needed for each flexion cycle and each extension cycle ranged from 3 to 7 days per one cycle. We repeated the flexion and extension cycles three times, thus requiring a period of 18–40 days. We then removed the fixator and placed the patients in a long-leg cast in extension for 5 weeks. In the last eight patients we put the cast on for 1 week only, and then applied an above-knee brace fixed in extension for 2 months.

Physiotherapy was performed by the patients and their families and not by professional physiotherapists. The parents were instructed to encourage their children to do active movement of the hips, ankles, and feet for 10 minutes following each distraction cycle. We advised the patient to walk using crutches the second day after the operation. Gradual weight bearing on the operated limb was encouraged once the deformity was corrected. After fixator removal, active and passive flexion and extension movement was allowed. The arc of motion was recorded every other week during followup visits.

After cast removal, for the first year followup the patients were assessed clinically every month and radiographically every three months, after which the patients were assessed clinically and radiographically every year. Fourteen of the 50 patients (28%) were assessed at last followup by their local doctors. At each followup visit we determined knee flexion angle (measured by HG and FM, independently and using the average readings recorded), range of motion of the knee, stability, and healing index (the numbers of days in the fixator until consolidation of the regenerate). The range of motion was measured by goniometer.

Results

The mean angle of maximum extension to maximum flexion improved from a preoperative average of 68° (range, 25°–140°) to an average of 3.5° (range, 0°–20°) after fixator removal. At last followup the average angle was 13.5° (range 0°–70°). The average time in the fixator was 4 months (range, 1.5–10.5 months). For the first 42 patients the average total arc of motion remained almost unchanged when comparing the preoperative (mean 48°; range 0 to 66°) with the followup results (mean 52°; range 0 to 90°). For the last eight patients there was a marked improvement from preoperative (mean 40°; range 10 to 70°) to postoperative (mean 67°; range 35 to 110°) average.

Of 20 bilateral nonambulatory patients, 18 could walk at last followup with ($n = 15$) or without ($n = 3$) crutches. The two nonambulatory patients with polio residuals and bilateral deformities could walk using knee-ankle-foot orthosis and two elbow crutches. Mild knee instability

occurred in four patients (including the two patients with bilateral deformity), although this did not seem to influence walking. Both patients with lumbosacral agenesis had recurrence of the deformity but both were still walking at last examination (Fig. 2).

Five patients (7%) had recurrence of the deformity. The etiology was arthrogryposis multiplex congenita in four patients and sacral agenesis in the other. The fixator was reapplied in the four patients with arthrogryposis. The degree of flexion contracture at the last followup was 50°, 48°, 68°, 60°, and 70°. Their followup times were 2, 4, 6, 4, and 3 years; and their arc of motion was 20°, 25°, 34°, 30°, and 5°, consecutively. The magnitude of bone lengthening in those six patients with lengthening ranged from 4 to 8 cm. The healing index was 38 days/cm.

All patients had some evidence of pin tract infection. In three patients an infected half pin had to be removed while a single half pin was replaced in another case. Knee subluxation occurred in three patients; two of these had subluxation preoperatively and none of them had further treatment. Of the five patients who had preoperative knee subluxation all were reduced during correction of the knee flexion deformity. Partial recurrence of the subluxation developed in two of these five patients during followup but these two patients had no pain or functional limitation and the families refused any further treatment. Knee stiffness occurred in two patients, with a marked reduction of the arc of motion at last followup; in these patients the preoperative arc of motion had been 45° and 55°, while at last followup the arc of motion was 25° and 20°, respectively.

Fracture related to treatment occurred in seven patients. Five of the fractures were related to the upper half pins. We observed fractures in two young patients (ages 2 and 3 years) where we used 3-mm half pins. Thereafter we shifted to smaller diameter half pins (2 mm) in patients with small bone diameters. The treatment in these two patients consisted of bed rest for 3 weeks until good callus formation followed by the initiation of distraction. Both femurs united with marked anterior angulation (40° and 52°), which remodeled gradually during followup; at last followup the angulation was 5° and 7° degrees respectively. In two of the other five in patients we extended the fixation to the uppermost part of the femur by another ring. In the fifth patient, the proximal part was small and osteoporotic, so we extended the frame to the pelvis by two supraacetabular Schanz screws and another arch. In the sixth patient a fracture in the upper tibia during fixator removal was treated by casting. In the final patient an epiphyseal injury a Salter-Harris II fracture occurred. We reversed the deformity and fixed the physis by two crossed wires. We removed fractured half pins in two patients.

Fig. 2A–I (A) Photo of a case with lumbosacral agenesis and bilateral severe knee flexion deformity and webbing. (B) Lateral radiograph of the right knee. (C) Lateral radiograph of the left knee. (D) A photo of the right knee during distraction. (E) A photo of the right knee at the end of distraction. (F) AP radiograph of the right

side after 3 years follow up. (G) Lateral radiography at the same time showing recurrence of the deformity. (H) Lateral radiography of the left knee at last follow up with recurrence of the flexion deformity. (I) AP radiography of the left knee at last follow up.

Discussion

Many surgical procedures have been proposed to treat fixed flexion knee deformity: lengthening of the hamstrings, posterior capsulotomy [1, 8, 24], epiphyseodesis of the distal femoral growth plate, femoral or tibial osteotomy [18, 26], femoral shortening [22], or arthrodesis. Although soft tissue releases do not seem very efficient in correcting the deformity, osteotomies are effective but change the anatomy of the joint [7]. Massive soft tissue release may lead to joint instability [10]. Gradual extension using external fixators has been advocated by several investigators [6, 12, 23], but the variability of the conditions for which these were used and the variability of treatment makes generalization difficult. Using a consistent approach, we determined the degree to which gradual distraction would improve flexion contractures and arcs of motion, how often it would convert nonambulatory to ambulatory patients, and the complications of the treatment.

Our study has several limitations. While the deformities resulted from different causes we tried to deal with deformities in a more or less uniform way. No single institution would likely have a substantial number of available patients with same etiology but a relatively large number of patients support our observations. The followup is also relatively short but comparable to that in other papers [11, 12]. Many patients came from abroad, so they were followed by different orthopaedic surgeons and may result in variable followup data. However, we were able to get copies of clinical and radiographic records of those patients at their last followup. Despite these limitations, this study suggests the effectiveness of gradual distraction using a circular frame in the management of knee flexion deformity whatever the etiology.

The acute nonoperative or operative treatment of severe flexion deformities is associated with relatively high risks of serious complications such as insufficient correction, skin necrosis, neurovascular problems, leg-length discrepancy, posterior subluxation of the tibia, fracture of the femur, and recurrence of the deformity. Ilizarov correction without any surgical incision improves nonoperative methods by allowing gradual correction of the complex deformities of the knee [5]. It also makes possible the lengthening of the bone (4 to 8 cm) to compensate for leg-length inequality and to correct valgus or varus angulation concomitantly.

Soft tissue release concomitantly with external fixator application has been frequently used by authors [4, 6, 12, 16]. In one of these studies [6], four of 11 patients had undergone previous posterior soft-tissue release operations, and for three patients with popliteal webbing, tenotomy of the medial and lateral hamstrings was performed. In

another study, eight of 14 knees had hamstring releases [12]. According to the law of tension stress distraction, a rate of 1 mm per day would lead to activation of collagen growth [16]. Nerves are known to regenerate at 1 mm per day following axonotmesis. Vessels retain proliferative activity and can usually respond to gradual distraction by growth. Distraction of the muscles is less predictable [4]. We performed no soft tissue release in any patient. Rather, we applied arthrodiastasis by transferring the forces from the bone to the soft tissues including ligaments, tendons, muscles and neurovascular structures in all except two patients.

In Egypt there have been no new infections of poliomyelitis in the last 3 years [25]. However, there remain many patients with late sequelae of the disease, such as muscle weakness, bony deformities, and joint abnormalities. Flexion knee deformity is one of the most common problems [18]. In patients with unilateral deformity and quadriceps paralysis, the patient may need to support his knee by putting his hand above the knee to walk. The patient usually is unable to walk in bilaterally severely affected knees or flail legs [18]. Treatment with hamstring fractional lengthening and supracondylar femoral extension osteotomy has been successfully applied to such cases [9]. In that report, bone shortening was applied if the flexion deformity was greater than 30° to avoid neurovascular complications. However, given bone shortening of an already shortened bone we did not favor this approach with our patients. Leong et al. [18] reported substantial loss of the range motion after treatment of patients with contractures greater than 40°. This constitutes a real problem for patients whose homes were fitted with outdated toilets that necessitated squatting. We did not encounter this problem since our patients with poliomyelitis gained motion.

Epiphyseal injury during nonsurgical correction of knee flexion deformity has been previously reported. In one study, the incidence was 23% of treated patients [6]. Caution should be exercised when treating growing children because the physal plates often have lower yield strengths than the fibrous joint contractures [11]. Also, some authors recommend fixation of the epiphysis with K wires during fixator application and release of the hamstrings [6]. Therefore, we expected to have a higher incidence of this complication as we did not release tight soft tissue structures. We faced the problem of epiphyseal injury during distraction in only one case. Overdistraction from the start (the hinges were placed anteriorly) may have minimized the incidence of this problem in our patients. We do not believe fixation of the epiphysis by a single wire in the coronal plane would prevent fractures in the sagittal plane.

Brunner et al. [3] reported acute respiratory distress syndrome (ARDS) after removal of a bilateral circular frame above and below the knee. They attributed ARDS to

the distribution of endotoxins of the germs located at the entry points of the K wires into the blood circulation. They recommended prophylactic antibiotics during the 3 days before removal of the pins. In our series we had 21 patients with bilateral deformities, in 17 of whom the fixator was removed on both sides at the same time. Nine had obvious pin tract infection during the time of removal. None of these patients received prophylactic antibiotics before removal of the frame. We observed no ARDS in our patients.

In 11 patients (13 knees), Damsin and Ghanem [6] reported recurrence of the deformity in four (one case of popliteal angioma and three with congenital webbing) at an average of 1.7 years (0.75–2.9 years) after removal of the fixator. The five poor results (7%) in our study were also due to recurrence of the deformity with either arthrogryposis multiplex congenita or sacral agenesis. Arthrogryposis is rare heterogeneous group of disorders with multiple congenital joint contractures. The muscles have an insufficient potential to grow. Bone growth causes relative shortening of the muscles that lead to substantial tendency of recurrence after management of deformities [3]. In patients with distal arthrogryposis the chances of walking are good, while those with amyoplasia are likely dependent on mobility aids throughout their lives [20]. The most common form of arthrogryposis is amyoplasia. Kroksmark et al. [17] in 2006 investigated the relationship between joint contractures and the functional status for 35 patients. None of the community ambulatory had knee flexion contractures exceeding 20°. In 10 of our patients, all four limbs were affected, and only the lower limbs in six patients. In our study all patients were amyoplastic.

One study in which femoral extension osteotomies for correction of knee joint contractures were reported, a loss of correction at a rate of 0.9° per month was noted after the operation, although solid bony fusion of all osteotomies were achieved [18]. We tried to delineate the rate of loss of correction every year but we could not because the patients did not adhere to followup dates.

Of the orthopaedic problems in patients affected with lumbosacral agenesis, knee flexion contractures with popliteal webbing were the most difficult to treat. For severe knee deformity, knee disarticulation and prosthetic fitting were the most effective treatments [21]. Amputation is not an acceptable solution in our culture.

Treatment of flexion knee contracture by a circular frame is an effective method that also allows a possibility to correct other deformities, to reduce the joint, and to lengthen the bone concomitantly. Recurrence of the deformity appears to depend on the etiology and not the type of treatment in patients with bilateral deformities. However, the relatively high rate of recurrence of the deformity is still unsolved.

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