Original Article

Gradual correction of knee flexion contracture using external fixation

Ettore Vulcano, Jonathan S. Markowitz[1], Austin T. Fragomen[2], S. Robert Rozbruch[2]

Department of Orthopedics, Icahn School of Medicine at Mount Sinai, [1]Limb Lengthening and Complex Reconstruction Service, Hospital for Special Surgery, [2]Limb Lengthening and Complex Reconstruction Service, Hospital for Special Surgery, Weill Cornell Medical College, New York, NY, USA

Abstract

Introduction: Knee flexion contracture (KFC) is a debilitating condition that may affect patients with neurogenic conditions, congenital deformities, posttraumatic deformities, and after total knee replacement. The recurrence rate of the deformity following either operative or nonoperative treatment remains high. The aim of the present study is to assess clinical outcomes of patients with KFCs and associated ankle equinus using gradual correction with a circular external fixator (CEF).

Methods: Twenty-one patients with knee flexion contraction were treated using a CEF. Seven patients were also simultaneously treated for ankle equinus. All but two patients underwent a combination of open or arthroscopic knee arthrolysis, distal hamstrings lengthening, and gastrocsoleus release. The CEF was applied to match the residual deformity, following the minimal incision soft-tissue release.

Results: Mean follow-up was 13 months. The mean range of motion (ROM) at final follow-up was −10° extension, 64° flexion, 9° ankle dorsiflexion, and 29° ankle plantar flexion. The difference between preoperative and postoperative ROMs was statistically significant ($P < 0.05$).

Discussion: The present study suggests that gradual distraction using a CEF is a safe and effective technique in the management of KFC and concurrent ankle equinus. It is crucial to maintain the postoperative correction with braces for at least 1–3 months, depending on the severity of the condition.

Key Words: Equinus, external fixator, knee contracture, knee flexion contracture, Taylor Spatial Frame

Address for correspondence:
Dr. Ettore Vulcano, Icahn School of Medicine at Mount Sinai, 5 E 98th St., New York, NY 10029, USA. E-mail: ettorevulcano@hotmail.com
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Introduction

Knee flexion contracture (KFC) is a debilitating condition that may affect patients with cerebral palsy (CP), congenital deformities, posttraumatic deformities, and after total knee replacement. In KFCs, the mechanical axis of the limb falls posteriorly to the knee, thus placing increasing demand on the quadriceps muscle to resist the progressive crouch.[1] KFCs cause crouch gait and excessive energy consumption during walking, making daily activities difficult such as standing, reaching for objects, and even walking.

Several non-operative treatments including serial casting,[2-5] reverse dynamic sling[6,7] and extension de-subluxation hinges[8] have been indicated to correct mild to moderate contractures. Several operative approaches including hamstring tendon lengthening with posterior knee capsulotomy,[9,10] distal femoral extension osteotomy[11] and guided growth with anterior distal

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femoral hemiepiphysiodesis in skeletally immature patients,[12] have all been indicated to correct the KFCs.[1] However, the recurrence rate of these non-operative and operative procedures can be very high.

Acute correction of KFC with soft tissue release, osteotomy, or both may lead to serious complications.[10] In contrast, gradual correction of KFC, a circular frame and a constrained hinge, avoids acute stretch injury to soft tissues and prevents compression of the anterior joint. Furthermore, gradual correction with histogenesis leads to soft tissue lengthening which should make the contracture less likely to recur. Our study aims to assess clinical outcomes, including range of motion (ROM) and the use of walking aids, of patients with KFCs using gradual correction with a circular external fixator (CEF).

Methods

Between 2004 and 2015, 21 patients with knee flexion contraction were treated using a CEF. Seven patients were also simultaneously treated for ankle equinus. Two orthopedic surgeons from the same institution treated all patients. Fourteen patients (67%) were male, and 7 (33%) were female. The mean age was 45 years (range, 20–60 years). Etiologies for the contractures were neurogenic (11 patients), after total knee replacement (5 patients), posttraumatic (3 patients), and fibromatosis (2 patients). The degree of KFC was measured clinically using a goniometer. The patient was placed in the supine position while the examiner asked the patient to extend the knee maximally. The examiner placed the goniometer at mid-patellar level at the lateral femorotibial axis and aligned one arm of the goniometer with the greater trochanter and the other arm with the lateral malleolus, with full extension of the knee as 0°. Mean preoperative ROM was −44° extension (range, −10°–−120°), 96° flexion (range, 10°–130°). The degree of equinus contracture of the ankle was measured clinically along the middle plane of the lateral aspect of the leg and plantar surface of the foot, with neutral position of the foot as 0°. Mean preoperative ROM was −23° ankle dorsiflexion (range, −10°–−50°) and 41° ankle plantar flexion (range, 30°–50°).

Technique

All but two patients underwent a combination of open or arthroscopic knee arthrolysis, distal hamstrings lengthening, and gastrocsoleus release. All total knee arthroplasties (TKAs) underwent open debridement for arthrofibrosis. Arthrolysis was done when there were adhesions in the joint and the patella was stiff. Arthrolysis included excision of scar tissue from the prepatellar space, medial and lateral gutters, and mobilization of the patella with medial and lateral retinacular releases, and release of adhesions in the suprapatellar space. In the TKA patients, the hamstrings were not tight and did not require to be released.

The CEF was applied to match the residual deformity, following the minimal incision soft tissue release. The knee and ankle were never forcefully manipulated to correct the contractures to prevent injury to the neurovascular structures. The CEF was prepared with one or two rings above and one or two rings below the knee joint.[16] The rings were connected using the hexapod Taylor Spatial Frame Struts (Smith and Nephew, Memphis, TN, USA) or hinges from the Ilizarov frame. Epiphysis needs to be avoided in children. In severe deformities, epiphyseal wires may be considered to protect displacement of the physis during correction. None of the cases in our series required that.

The hinge point of the knee was at intersection of the posterior cortex and Blumensaat's line. When using a hexapod frame, the origin and corresponding point were set at the hinge point and distraction was added to prevent crushing the articular cartilage of the knee. The formula: Minimum lengthening needed = W sin (deformity angle), where W is the distance from the hinge point to the anterior edge of the knee joint. When using an Ilizarov frame, the hinge placement can be anterior on the bisector line to add some distraction and prevent compression of cartilage. Our preference is to place the hinge directly on the hinge point of the knee and to add distraction by distracting the tibial ring and not effecting the location of the hinges at the center of rotation of the knee.

The hexapod frame provides very precise deformity correction. If a translation deformity develops, it can be corrected with a residual deformity correction. The disadvantage of the hexapod frame is that it cannot be unlocked for free ROM exercises.

The Ilizarov frame is less precise and correction of unintentional translation is more difficult, but it allows unlocking of the frame for free ROM exercises. Our current practice is to use the hexapod frame since we have not found the free ROM exercises to be useful or to have an effect on outcome ROM.

Correction of deformity started the first postoperative day, with the posterior capsule and the Achilles tendon representing the structure at risk at the knee and ankle, respectively. The rate of distraction was set at 1 mm/day. The aim was to hypercorrect the knee to 5–10° of hyperextension, and the ankle to 10–15° of dorsiflexion, to prevent recurrence of the contracture. Patients were monitored by standard anteroposterior and lateral X-rays every 1–2 weeks to rule out joint subluxation and monitor progress. At the end of the correction, the external fixator was maintained in full extension of the knee

and ankle joints for at least as long as the correction time.[13,14] After removal of the external fixator under general anesthesia, we applied an off-the-shelf spring-loaded dynamic splint for 1–3 months.

Paired *t*-test is used to evaluate the parametric data before and after the surgery. A $P < 0.05$ is considered statistically significant.

Results

The mean duration of follow-up was 13 months (range, 10–18 months). The mean duration of external fixation was 3 months (range, 3–4 months). Mean ROM at final follow-up was − 10° extension (range, 0°–−50°), 64° flexion (range, 20°–100°), 9° ankle dorsiflexion (range, 0°–25°), and 29° ankle plantar flexion (range, 20°–40°). The difference between preoperative and postoperative ROMs was statistically significant ($P < 0.05$) [Tables 1 and 2]. At the knee, the preoperative arc of motion of 52° was similar to the postoperative arc of motion of 54°. Conversely, the arc of motion at the ankle increased from 18° to 38° ($P < 0.001$). Two patients with neurogenic etiologies required knee manipulation for excessive knee stiffness in extension. Fifteen patients (71%) developed a superficial pin infection that was successfully treated with oral antibiotics. One patient (4.8%) developed a femoral neck fracture secondary to pin loosening. Two patients (9.5%) had recurrence of the KFC (40° and 45°, respectively) without any benefit compared to preoperative deformity. Both patients had neurogenic etiologies. The remaining patients were all able to stand and walk with fewer or no aids compared to the preoperative state [Figures 1-3].

Discussion

KFCs cause marked physical disability. Progressive knee flexion places more force on the quadriceps, leading to overstretching of the muscle fibers and the infrapatellar tendon, causing patella alta, patellar fragmentation, chondromalacia, joint instability, muscle weakness in terminal extension and pain secondary to patellofemoral degenerative joint disease.[12,15,16] This increases the loading on several joints, especially on the patellofemoral joint, and becomes an important problem causing anterior knee pain and stress fractures of the patella and tibial tubercle.[17,18]

Table 1: Compares pre- and post-operative range of motion at the knee and ankle joints

Range of motion	Mean preoperative (range)	Mean postoperative (range)	*P*
Knee extension	−44° (−10°-−120°)	−10° (0°-−45°)	<0.05
Knee flexion	96° (10°-130°)	64° (20°-90°)	<0.05
Ankle dorsiflexion	−23° (−10°-−50)°	9° (0°-25°)	<0.05
Ankle plantar flexion	41° (30°-50°)	29° (20°-40°)	<0.05

Figure 1: Preoperative photo demonstrating severe bilateral knee flexion contracture and ankle equinus in a non-ambulatory patient

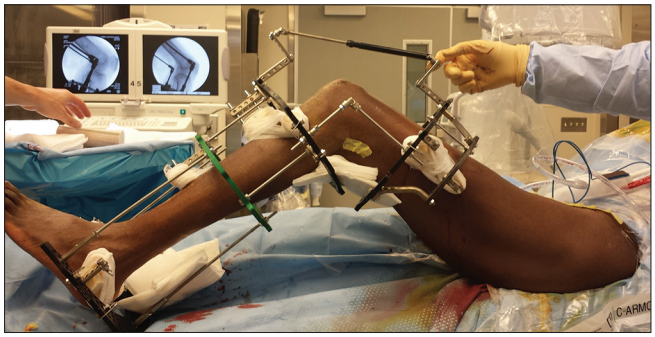

Figure 2: Immediate postoperative photo following application of the external fixator

Figure 3: The photo demonstrates the patient at 1 year follow-up after bilateral correction of the deformities. The patient was able to ambulate with a walker

Table 2: Summarizes the knee results for all patients

Patient	Age	Etiology	Preoperative flexion (°)	Preoperative extension (°)	Preoperative arc of motion (°)	Preoperative walking ability	Postoperative flexion (°)	Postoperative extension (°)	Postoperative arc of motion (°)	Postoperative walking ability
1	20	Posttraumatic	80	45	35	Walked with aids	45	0	45	Walked with no aids
2	62	Total knee replacement	80	35	45	Walked with aids	60	5	55	Walked with no aids
3	26	Total knee replacement	70	40	30	Walked with aids	55	5	50	Walked with no aids
4	62	Total knee replacement	80	35	45	Walked with aids	60	5	55	Walked with no aids
5	32	Neurogenic	120	50	70	Nonambulatory	80	5	75	Walked with no aids
6	25	Neurogenic	115	30	85	Walked with aids	70	10	60	Walked with no aids
7	63	Neurogenic	60	60	0	Nonambulatory	60	5	55	Walked with no aids
8	63	Neurogenic	50	50	0	Nonambulatory	50	10	40	Walked with no aids
9	47	Posttraumatic	120	25	95	Walked with aids	70	0	70	Walked with no aids
10	51	Neurogenic	130	60	70	Nonambulatory	65	15	50	Walked with aids
11	51	Neurogenic	110	60	50	Nonambulatory	70	15	55	Walked with aids
12	41	Posttraumatic	130	50	80	Walked with aids	65	5	60	Walked with no aids
13	69	Neurogenic	40	40	0	Nonambulatory	40	5	35	Walked with aids
14	68	Total knee replacement	90	30	60	Walked with aids	60	0	60	Walked with no aids
15	43	Neurogenic	120	120	0	Nonambulatory	65	10	55	Walked with no aids
16	35	Fibromatosis	90	35	55	Walked with aids	60	15	45	Walked with no aids
17	35	Fibromatosis	80	35	45	Walked with aids	65	20	45	Walked with fewer aids
18	35	Neurogenic	120	30	90	Walked with aids	80	0	80	Walked with no aids
19	35	Neurogenic	120	45	75	Walked with aids	80	45	35	No benefit from surgery
20	21	Neurogenic	130	40	100	Walked with aids	90	40	50	No benefit from surgery
21	58	Total knee replacement	90	40	50	Walked with aids	50	0	50	Walked with no aids

Hoffer *et al.* found that a KFC >30° was incompatible with functional ambulation.[19]

Serial casting is one nonoperative treatment option for KFCs. Fernandez-Palazzi and Battistella utilized a serial casting/wedging technique in the management of 58 patients with flexion contractures resulting from hemophilia. The pretreatment flexion deformity improved by 9.1°. They determined that it was possible to achieve −5° of extension in 4 weeks, with little improvement thereafter.[4] Westberry *et al.* performed a retrospective review of all CP patients with resistant or recurrent KFCs treated with serial stretch-casting. They noted correction to within 10° of full extension in 76% of patients. They reported that 17 of the 26 cases maintained a flexion angle of <5° at the 1-year follow-up.[5] Narcis reported that the amount of corrective force that may be applied with casts, splints, and braces is limited by the inability of the skin to tolerate direct pressure.[20] Factors that predicted successful maintenance of correction from serial casting were if the age of the patient was <12 years and if the initial knee flexion angle was <15°.

Various surgical procedures have been proposed to treat severe fixed KFCs. Wallny *et al.* performed a retrospective study of hemophiliac patients treated with hamstring release and posterior capsulotomy. Patients had KFCs that ranged from 10° to 45° At mean 12.5 years follow-up, only 11 patients maintained the correction.[9] Heydarian *et al.* studied 42 knees with severe KFCs (average 69°) that were treated by posterior capsulotomy followed by traction and/or casting. At 2.5 years follow-up, 39 knees maintained correction to <15° of flexion. They recommend this treatment for severe flexion contracture of the knee, in patients with poliomyelitis, but not in patients with insensitive skin.[10] Wallny *et al.* reported that after the operation, there was still muscular imbalance, which needed intensive treatment to avoid instability or impaired range of movement.[9]

Distal femoral extension osteotomies are an alternative surgical treatment to correct KFCs. DelBello and Watts performed a retrospective study of patients with arthrogryposis multiplex congenita and severe KFCs. They performed 32 osteotomies in 13 patients. All patients had a minimum of 24-month follow-up. During follow-up, there was a loss of correction of 22° at a rate of 0.9°/month. They observed a recurrence of the flexion contracture in all patients, which could be related to the remodeling of the distal femur.[11] Osteotomies seem to be effective but change the anatomy of the joint.[11,21] Balci *et al.* reported that distal femoral extension osteotomies change the arc of motion.[13] Leong *et al.* reported substantial loss of ROM after treatment of patients with contractures >40°.[22] They reported that of 17 knees having a contracture of 40°

or more before operation, only four had a postoperative range of 120°–155°. The same range, however, was found in 53 out of 72 knees that had a contracture of <40°. Two patients developed posterior tibial subluxation, and both had a significant amount of pain.[22]

The use of CEFs to correct KFCs offers a number of advantages. It allows progressive correction of complex knee deformities with simultaneous correction of associated foot deformities and limb length discrepancies. External fixator application along with soft tissue releases has been used by other authors.[13,23] Balci *et al.* studied six hemophiliac patients with KFCs that underwent correction using external fixators. The mean arc of motion was 58.3° preoperatively and 51.6° postoperatively. At 8 years follow-up, patients' arc of motion lost an average of 6.7°. They found that the total arc of motion changed, which they attributed to the late start of physical therapy because of the risk of bleeding for these patients during the correction period. He also reported a recurrence of 10° of flexion deformity on average in their series at 7.9 years follow-up.[13]

Concurrent treatment of ankle equinus was necessary for one-third of our cohort. Carmichael *et al.* reviewed 23 cases of postburn ankle equinus treated by the Ilizarov technique of gradual distraction histogenesis. They reported that the rate of recurrence after correction of equinus deformity in children using the Ilizarov technique was 74% and that the average time to recurrence was 17.3 months.[23] Emara utilized the Ilizarov technique for the treatment of acquired equinus deformity in children. A cohort of 26 children was managed by a percutaneous tendo-Achilles lengthening, followed by application of an Ilizarov external fixator. The rate of recurrence, degree of equinus at recurrence, and number of episodes of external fixation surgery showed statistically significant differences between the groups.[24]

Our study aimed to assess clinical outcomes, including ROM and the use of walking aids, in patients with KFCs and associated ankle equinus using a CEF. Hosny and Fadel retrospectively studied fifty patients with fixed flexion knee deformities that were treated with the Ilizarov external fixator. [21]

They reported that the mean angle of maximum extension to maximum flexion improved from a preoperative average of 68° to an average of 3.5° after fixator removal. At last follow-up, the average angle was 13.5°. After a minimum follow-up of 1 year, 18 of 20 of the preoperative nonambulatory patients who had bilateral surgery were able to walk.[21] Our study reported similar results. Only two patients had recurrence of the KFC without any benefit compared to preoperative deformity. Both patients were affected by neurogenic conditions and had been living with the deformity for over 20 years. The remaining patients were all able to stand without aids ($n = 12$), walk with fewer aids ($n = 2$) compared to preoperative state, and sit more comfortably ($n = 5$). Hosny and Fadel did not perform soft tissue releases in any patient. Rather, they 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.[21] Our cohort included patients with KFCs and concurrent ankle equinus. Our use of an external fixator with concurrent soft tissue releases was justifiable to prevent a plantar flexion contracture while the external fixator stretches the gastrocnemius muscle into extension. The use of external fixators is effective in treating concomitant ankle equinus as our patients saw an overall increase in ankle ROM from 18° to 38°. The use of an external fixator prevented the risk of stretching the sciatic nerve and its branches and did not cause large skin defect posteriorly, both of which could have occurred by acute correction of the deformity.

We observed a clinically and statistically significant improvement between preoperative and postoperative ROMs. In our study, preoperative arc of motion, 52°, and postoperative arc of motion, 54°, was almost identical. This finding is consistent with previous work by Herzenberg *et al.*, who studied a cohort of 14 patients with an average preoperative KFC of 60°. They too report that the functional position of patient's arc of motion improved significantly while the average total arc of motion remained essentially unchanged when comparing preoperative (59°) with the follow-up results (63°).[25] However, flexion was sacrificed in favor of extension to provide a more functional ROM. This was clinically evident as most patients were able to stand or walk without or use fewer aids and were all able to sit more comfortably. Moreover, application of the CEF not only fully corrected the equinus contracture but also significantly increased arc of motion by 20°.

Damsin and Ghanem used the Ilizarov technique to treat severe flexion deformity of the knee in 13 knees. They reported recurrence of the deformity in four cases at an average of 1.7 years after removal of the fixator.[26] Huang used Ilizarov frames in 26 patients for correction of severe contractures in 10 knees and 19 ankles. At minimum 3 years follow-up, 11 contractures had recurred.[27] Hosny and Fadel reported a 7% recurrence of the deformity at a minimum of 2-year follow-up.[21] Despite a shorter follow-up, all but two patients in the present study reported an overall improved function compared to the preoperative state.

Our study had some limitations. These include a limited follow-up, a small number of patients, the retrospective nature

of the study, and the lack of validated questionnaires to assess clinical outcome.

Conclusion

The present study suggests that gradual distraction using a CEF is a safe and effective technique in the management of KFC and concurrent ankle equinus. It is crucial to maintain the postoperative correction with braces for at least 1–3 months, depending on the severity of the condition. While functional ROM and patient mobility were improved after surgery, the arc of motion in the knee did not change. Patients with a long-standing history of neurogenic conditions determining the flexion contracture should be informed of being at a greater risk of recurrence of the deformity.

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Conflicts of interest

There are no conflicts of interest.

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