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Original Article

Surgical Approach to Correction of Severe Knee Malalignment in a Pediatric Population in Tanzania

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Abstract

Aim: Severe knee malalignment in children usually needs surgery with different options available in surgical approaches. The aim of this study was to report the results of the surgical correction of severe knee malalignment in children treated with femoral and tibial osteotomy, temporarily fixed with percutaneous Kirschner wires, in a low- and middle-income country (LMIC), with limited medical resources.

Materials and methods: Thirty children (age range 4–9 years) with severe knee malalignment were observed and surgically treated in a small children hospital located in the Tanzanian rural outback. A total of 53 deformities were treated. Thirty-two knees presented varus deformity and 21 knees presented valgus deformity. In 9 cases, femoral osteotomy alone was performed, tibial osteotomy alone in 28 cases, combined femoral and tibial osteotomy in 16 cases. Fixation was obtained with crossed percutaneous Kirschner wires, and a post-operative long-leg cast immobilization was applied.

Results: Mean pre-operative varus passed from 40°±4 to post-operative 5°±6 valgus. Mean pre-operative valgus passed from 39°±4 to post-operative 8°±5 valgus. Complications included delayed healing of the wounds, skin suffering at the outlet of Kirschner wires, knee stiffness, undercorrection and overcorrection of the deformity. Results were considered excellent in 18 cases, good in 21, fair in 11, poor in 3.

Conclusions: This technique allowed us to obtain satisfactory correction of severe knee malalignment with less invasive surgery. Inexpensive hardware such as Kirschner wires, combined with cast immobilization, allowed satisfactory fixation of the osteotomy, and reduction of the overall cost of surgery, as it should be desirable in LMICs.

Keywords

Blount disease, knee malalignment, limb malalignment, osteotomies, pediatric

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INTRODUCTION

A severe knee malalignment may be the consequence of a physiologic angular deviation that evolved into deformity, it may develop within a plethora of skeletal and general diseases, or it may result from trauma. If untreated, the severe alteration of the knee axis may produce suffering of the growth plates of the lower limb and produce a deformity also in the hip and the ankle joint.[1]

During growth, knee malalignment can be treated nonsurgically in some milder cases or surgically in more severe cases via different surgical approaches. A less invasive surgical approach consists in hemiepiphyseal arrest of the growing cartilage of the knee (femoral, tibial or both). More invasive surgery includes different kinds of osteotomies, to obtain immediate correction of the deformity (using either internal or external fixation), and distraction osteogenesis with external fixator, to obtain a gradual correction. Considering all variables related to the etiopathogenesis of the angular deformity of the knee, the age of observation and the different surgical options, the optimal timing for treatment and the surgical procedure are still causes of concerns and debated.[2-8] Moreover socio-economic environment and health care assistance could affect the approach to the patients and the possibility to consider all the different options of treatment and finally to prejudice adequate patient's follow-up, as it often happens in low- and-middle-income countries (LMICs). Severe knee malalignment, particularly secondary to Blount's or metabolic diseases, is more frequent in African people than in Caucasian, and in LMICs, children often come late to medical observation after they have already developed a severe deformity. We reviewed a series of children affected by severe angular deformity of the knee observed and treated, with limited medical resources, in a LMIC, the Tanzanian outback.

AIM

The aim of the study was to report the results of a series of 30 children affected by severe knee malalignment, surgically treated with closing wedge corrective osteotomy of femur, tibia, or both, fixed with temporary percutaneous Kirschner wires and casting.

MATERIALS AND METHODS

Fifty-one children presenting with severe angular deformity of the knee were observed and surgically treated in a small children hospital located in the Tanzanian rural outback, where the senior authors used to work for years as volunteers. Because of the particular local environment and the resulting difficulties to follow-up and to re-call patients for further evaluation after surgery, many patients were lost at follow-up. Thirty children (18 males and 12 females) regularly returned for scheduled controls and they were re-called to be checked again some years after surgery, so they were considered eligible for this study. The age of the patients at time of surgery ranged from 4 to 9 years (average age 6 years). Twenty-three patients presented bilateral deformity, whereas the deformity affected only one side in 7 cases, for a total of 53 knees treated. It was difficult to obtain a complete history for each child, but at least, developmental milestones such as the start of ambulation and the age of onset of the deformity were recorded. Clinical evaluation assessed the kind of the deformity (varus, valgus, procurvatum, recurvatum), knee range of motion and stability, limb length discrepancy, limping and gait abnormalities, pain and other associated complaints. Imaging included only standard standing anteroposterior and lateral view radiographs of the knee, not of the best quality among other things. Radiographic evaluation assessed the kind and the site of the deformity (femur, tibia or both), and peculiarities of the bone, the growing cartilage and the joint.

Clinical and radiographic evaluation allowed to diagnose Blount's disease in 12 patients, malnutrition and rickets in 4 patients, post-traumatic deformity in 3 patients, and to hypothesize chondrodysplasia in 3 patients, whereas in the remaining 8, the deformity was considered idiopathic or the underlying disease remained unclear. Thirty-two knees presented varus deformity, whereas 21 knees presented valgus deformity **(Table 1)**.

Because of practical and economic limitations that restricted the availability of full-limb radiographs (including the femoral head and the ankle) for assessing the mechanical axis of the knee, the anatomical tibio-femoral angle (TFA)[9], defined as the angle between the anatomical axis of the femur and the anatomical axis of the tibia, was used to evaluate the degree of the deformity. This was measured on antero-posterior standing radiographs of the knee, including as much as possible of the femoral and tibial shaft. The anatomical axis of the femur was determined tracing the line bisecting the middle third of the femoral shaft, as well as the anatomical axis of the tibia was the line traced from the point bisecting the middle third of the tibial shaft. The TFA was determined at the intersection of these two lines. On standing radiographs, the orientation of the joint line with respect to the ground suggested if the deformity was primarily due to either femoral or tibial deformity. Furthermore, we evaluated the anatomical lateral distal femoral angle (LDFA) and the medial proximal tibial angle (MPTA)[9] in order to determine the single deformity of the femur and the tibia, and thus to plan surgery accordingly performing a femoral, tibial or a combined osteotomy, basing on the degree of each deformity. However, in case of varus deformity due to Blount's disease, tibial osteotomy was always performed. Usually, the surgery was planned attempting to obtain a slight overcorrection of the deformity.

Surgical treatment consisted in a subtractive osteotomy of femur, tibia or both, with removal of a bone wedge according to the kind and the degree of the deformity and the correction planned on radiographs. A lateral subtractive osteotomy was performed for correction of knee varus and a

Table 1. Demographic data

Deformity	Patients			Affected limb			Underlying diagnosis		
	M	F	Total	Unilateral	Bilateral	Total			
Varus	11	6	17	2	15	32	Blount's disease	24	(75%)
							Malnutrition / Rickets	2	(6%)
							Chondrodysplasia	4	(13%)
							Post-traumatic deformity	1	(3%)
							Idiopathic / Unclear	1	(3%)
Valgus	7	6	13	5	8	21	Malnutrition / Rickets	6	(28%)
							Chondrodysplasia	2	(10%)
							Post-traumatic deformity	2	(10%)
							Idiopathic / Unclear	11	(52%)

medial subtractive osteotomy for knee valgus. In case of bilateral deformity, if both femoral and tibial osteotomy were necessary, a first osteotomy was performed on only one of the two bones, bilaterally, and the second osteotomies were planned after 6 to 12 months from the first treatment.

Surgery was performed under spinal anesthesia, with pneumatic ischemic tourniquet at the thigh. Femoral osteotomy alone was performed in 9 cases and tibial osteotomy alone in 28 cases. Combined femoral and tibial osteotomy was performed in 16 cases, and 14 of these needed a two-stage treatment (first femoral and then tibial osteotomy) since the deformity was bilateral. In case of valgus deformity, before performing the osteotomy, prophylactic peroneal nerve decompression was performed, as described by Nogueira and Paley.[9-11] Osteotomies were performed using an oscillating saw and/or osteotomes. Femoral osteotomy was performed through a lateral approach in case of varus deformity or medial in case of valgus. With the lateral approach, the distal diaphysis of the femur was exposed gently elevating the vastus lateralis, whereas in case of medial approach, the bone was exposed retracting anteriorly the vastus medialis and posteriorly the sartorius and the adductor magnus, taking care to not damage the descending genicular artery and the popliteal neurovascular bundle. Under fluoroscopy, physeal cartilage was localized and before performing the osteotomy, a Kirschner wire was inserted just above, parallel to the joint line. A second Kirschner wire was then inserted just proximal to first, almost perpendicular to the anatomical axis of the femur, in order to delimit the bone wedge to remove, attempting to obtain a physiologic LDFA (about 80 degrees[9]) or a slight overcorrection. Between the two Kirschner wires, a transverse osteotomy was then performed removing a bone wedge according to the planning and it was fixed using two crossed percutaneous Kirschner wires. In four cases the wires were completely deepened to the bone and left inside afterwards. Surgical approach to proximal tibia also depended on the kind of deformity. In case of varus, a curved skin incision was made form the apex of the fibula to the tibial anterior crest. The antero-lateral muscles were gently detached in order to expose the proximal diaphysis of the fibula and the tibia, and protecting the common peroneal nerve a subtractive osteotomy of the fibula, just distally to the physis, was made. Under fluoroscopy, a transverse tibial osteotomy was then performed removing a bone wedge, with the same technique previously described, aiming to obtain a MPTA of about 90 degrees.[9] Again, fixation was obtained using two crossed percutaneous Kirschner wires, as described for femoral osteotomy, except in four cases where the wires were deepened and left inside afterward. Finally, antero-lateral muscles were reinserted. Conversely, in case of valgus deformity, a curved anteromedial skin incision was made from the medial tibial condyle to the anterior crest, and the bone was exposed taking care not to damage pes anserinus tendons. In these cases, peroneal osteotomy was not necessary.[12-16] Sagittal or rotational deformities were also considered in performing the osteotomy and then during the fixation in order to correct associated deformities along with varus or valgus, and at the end of the surgical procedure, realignment of the limb was checked clinically and through fluoroscopy. Closure was made in multiple layers and after surgery a long-leg cast was applied.

Cast was maintained for 6 weeks and weight bearing was not allowed. Six weeks after surgery the cast and the percutaneous Kirschner wires were removed and a second long-leg was applied for further 4 weeks, allowing weight bearing. After second cast removal, free weight bearing was allowed and physiotherapy was prescribed, consisting in active and passive mobilization of the knee, proprioceptive exercises and muscle strengthening. At last available follow-up, preoperative clinical and radiographic evaluation were repeated.

RESULTS

Surgical time ranged from about 30 to 70 minutes: mean 35 minutes in case of single osteotomy, 52 minutes in case of combined femoral and tibial osteotomy (monolateral surgery). No intraoperative complications occurred. No blood transfusions were necessary.

One case of delayed healing of tibial anteromedial wound and one case of delayed healing of tibial anterolateral wound were noted after postoperative cast removal, resolved with simple dressing. In three cases, an inflammatory reaction with skin suffering was observed at the outlet of the Kirschner wires, spontaneously resolved with dressing after removal of the wires. No deep infection occurred. No major neurological or vascular complications were reported.

All osteotomies healed. On radiographs, at the removal of first cast, callus formation was noticeable in all cases, and after second cast removal, obvious bone remodeling was noted. Mild knee stiffness after cast removal completely resolved with rehabilitation after 2 to 4 weeks. Moderate to severe joint stiffness was noted in two knees after removal of the cast, requiring a longer and tougher rehabilitation, with complete resolution after 6 and 8 weeks, respectively.

Average follow-up was 5 years (range 2–7 years). Basing on TFA, mean preoperative varus was 40°±4 (range 35°–51°) and mean preoperative valgus was 39°±4 (range 32°–48°). At last follow-up in those knees undergone correction of varus deformity, the alignment ranged from 15° varus and 22° valgus, with average 5°±6 valgus **(Fig. 1)**. The alignment of those knees treated for valgus deformity at last follow-up ranged from 18° valgus and 5° varus, with a mean of 8°±5 valgus **(Fig. 2)**. For what concern those children presenting a varus knee, we observed a greater deformity in case of Blount's disease and in those cases where

Figure 1. A 6-year-old boy presenting with bilateral severe varus deformity of the knee (**A**). Preoperative radiographic deformity (**B**). The anatomical tibio-femoral angle (TFA) was considered, as well as the anatomical lateral distal femoral angle (LDFA) and the medial proximal tibial angle (MPTA). Clinical (**C**) and radiographic aspect (**D**) two years after surgery, with a satisfactory result.

Figure 2. A 7-year-old boy with severe post-traumatic valgus deformity of the right knee (**A, B**). Degree of the planned correction checked (**C**). Satisfactory correction of the deformity (**D**).

a chondrodysplasia was hypothesized. In patients affected by Blount's disease, we obtained a more variable degree of correction. In these children, we reported a high rate of excellent results, but we also reported the poorest results in terms of undercorrection, involving a 5-year-old child with bilateral 42° varus pre-operatively and 12° and 15° varus post-operatively, and in terms of overcorrection, involving a 6-year-old child with 44° and 40° varus pre-operatively and, respectively, 16° and 22° valgus post-operatively (the latter considered as a poor result). No evidence of significant relationship was noted between the degree of the deformity, the age of the patient, and the time of surgery. The degree of correction seemed to not be strictly related to the degree of the initial deformity. For those patients with valgus knee, most of them presented with an idiopathic deformity that was generally less severe than in those patients affected by malnutrition, chondrodysplasia, or post-traumatic sequelae. Better results were mostly observed in the idiopathic forms, and lower results in those patients affected by malnutrition, even if the degree of correction was similar in all children. Anyway, the lowest correction was reported in a 6-year-old child with idiopathic deformity, presenting 38° and 36° valgus pre-operatively and, respectively, 18° and 14° valgus post-operatively **(Table 2)**.

The overall result was similar for varus and valgus knees, also considering the different groups of underlying diseases. Basing on knee alignment at last follow-up, 18 cases were considered excellent (0 to 10° valgus), 21 good (5° varus to 15° valgus), 11 fair (10° varus to 20° valgus) and 3 poor (varus >10°, valgus >20°) **(Table 3)**. Of these poor results,

Table 2. Results. Surgical treatment and degree of correction

Deformity	Underlying diagnosis	Osteotomy			Mean knee mechanical axis (range in brackets)	
		Tibial alone	Femoral alone	Combined	Pre-op	Post-op
Varus	Blount's disease	24			42° (36° – 46°)	4° valgus (15° varus – 22° valgus)
	Malnutrition / Rickets	2			36° (35° – 38°)	11° valgus (10° – 12° valgus)
	Chondrodysplasia			4	46° (40° – 51°)	9 valgus (5° – 14° valgus)
	Post-traumatic deformity	1			38°	8° valgus
	Idiopathic / Unclear	1			40°	11° valgus
	Total	28		4	40°±4 varus (35°-51°)	5°±6 valgus (15° varus – 22° valgus)
Valgus	Malnutrition / Rickets		2	4	43° (38° – 48°)	11° valgus (5° – 16° valgus)
	Chondrodysplasia			2	43° (40° – 46°)	14° valgus (12° – 15° valgus)
	Post-traumatic deformity		2		45° (42° – 48°)	9° valgus (8° – 10° valgus)
	Idiopathic / Unclear		5	6	35° (32° – 38°)	6° valgus (5° varus – 18° valgus)
	Total		9	12	39°±4 valgus (32°-48°)	8°±5 valgus (5° varus – 18° valgus)

Table 3. Rating of the results

Deformity	Underlying diagnosis	Results			
		Excellent	Good	Fair	Poor
Varus	Blount's disease	7	7	7	3
	Malnutrition / Rickets	1	1		
	Chondrodysplasia	2	2		
	Post-traumatic deformity	1			
	Idiopathic / Unclear		1		
	Total	11	11	7	3
Valgus	Malnutrition / Rickets	2	3	1	
	Chondrodysplasia		2		
	Post-traumatic deformity	2			
	Idiopathic / Unclear	3	5	3	
	Total	7	10	4	

two were judged an undercorrection rather than a relapse, and one was an overcorrection. Anyway, even in cases of residual deformity, no limping or pain during standing or gait were complained about.

DISCUSSION

Many authors advise correcting knee malalignment in children as early as possible to avoid complications due to the progressive nature of the disease. Temporary hemiepiphysiodesis is often advised because it represents a simple and less invasive surgery with a reported high rate of successful results and a low rate of complications, especially with modern fixation devices. Temporary hemiepiphysiodesis requires a careful assessment of the residual growth of the patient, which is sometimes not so easy to determine exactly.[17] Moreover, temporary hemiepiphysiodesis needs a close follow-up in order to plan removal of the devices, and all these issues make this kind of treatment less viable in LMICs, where, furthermore, some devices for hemiepiphysiodesis such as eight-plates may not be easily available and their higher costs limit their use. Osteotomies are also advised for correction of knee malalignment during growth, allowing both immediate and gradual correction of the deformity, but they generally represent a more demanding surgery. Femoral or tibial osteotomy can be fixed either using external fixators or internal devices. External fixation can be used both for acute and gradual correction of the deformity, offering the advantage to modify the degree of correction and limb alignment during treatment. Moreover, as reported by some authors, gradual correction of the deformity using external fixator seems to be more accurate than immediate correction.[18] Nevertheless, this kind of treatment needs adequate compliance by the patients and a careful follow-up; moreover, such a technique implies higher costs, and such devices are not always easily available in some parts of the world, particularly the poliaxial/Ilizarov fixators.[18-19]

Surgery in LMICs should carefully take into account all these issues, and the surgeon may experience great difficulty following patients who have undergone gradual correction with hemiepiphysiodesis or external fixation. In this series of patients, considering the severity of the deformity and all the concerns about a difficult follow-up, we performed immediate correction through osteotomies fixed with internal hardware. A single osteotomy of one or both bones, based on the severity of the deformity, as we performed in this series, allowed us to achieve adequate correction with a high rate of satisfactory results and acceptable surgical trauma. When the deformity involved both the femur and tibia bilaterally, we preferred to perform first a bilateral osteotomy of the same bone rather than a unilateral osteotomy of the femur and tibia, with the aim of obtaining, after the first operation, a certain symmetry of the lower limbs. We did this because we believed the patients would have better ambulation while waiting for the other bones to be corrected. Since the second surgery was performed, even a year after the first, we expected that the patients would have less difficulty to walk having symmetric knees rather than a unilateral straight knee and a severely valgus or varus contralateral knee. The use of percutaneous K-wires for fixation allowed a minor surgical trauma, with lower costs compared to other devices. Even if a long-leg cast was applied for some weeks after surgery, in this series we observed only low rate of knee stiffness, completely resolved with rehabilitation. Therefore, we advise to combine K-wire fixation with postoperative long-leg cast. We are aware of some remarkable limitations of this study, mostly concerning the non-homogeneous series of patients we considered and the different kinds of deformity we included, both varus and valgus, either involving femur or tibia or both. Moreover, difficulties were encountered in reaching the etiopathogenetic diagnosis in all the patients, and in some cases, the underlying disease remained unclear. Radiographic evaluation was carried out on poor-quality radiographs and this may have interfered with accurate measurements. Some authors suggest to evaluate knee malalignment on full-limb standing radiographs, including the femoral head and the ankle, in order to assess the mechanical axis of the knee.[20,21] However, when this kind of radiogram is not available, also the clinical evaluation[22] and the tibio-femoral axis[9] could be suitable, especially when measured on a standing radiograph of the knee, including from the mid-proximal third of the femoral shaft to mid-distal third of the tibial shaft. A longer follow-up should be desirable in order to observe the behavior of the physeal cartilage during growth and to assess the maintenance of correction until skeletal maturity, mostly in patients affected by metabolic or cartilage diseases. As stated by some authors, the growth of physeal cartilage contralateral to the hemiepiphysiodesis during treatment and the growth of the whole physis after hardware removal, as well as after an osteotomy, represent main concerns that are not always easy to be addressed, mainly in case of bone and cartilage diseases, exposing to risk of permanent overcorrection or loss of correction after the treatment. Moreover, recurrence of the deformity has been reported commonly in patients suffering by metabolic and dysplastic bone diseases, such as some patients in our series. Though other authors postulate that adequate restoration of the articular line could prevent recurrence of the deformity, and recurrence seems not to be strictly related to the specific kind of surgical procedure performed.

CONCLUSION

In our experience, we found that even a relatively simpler surgery could provide satisfactory results with the advantage of reducing the surgical trauma and the cost of the treatment, and without the need of a close follow-up. The surgery we described in this paper used to be routinely performed in the recent past, until the technical and technological improvement led to better results along with a more sophisticated approach to the correction of severe knee deformities. However, the good results that this surgery has ensured in the past can also be reached nowadays, mainly if other surgical approaches cannot be considered or performed. The experience that we report in this paper is mainly addressed to those surgeons who must necessarily work with limited resources, and our suggestion is to safely consider also this kind of surgery as a viable option, because, despite a low accuracy may be postulated, it can provide satisfactory results.

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Competing interests

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Author contribution

I.S.: manuscript preparation; M.N.: surgeon; study design; D.L.: surgeon; study design; D.F.: data acquisition; F.T.: revising the paper; C.F.: revising the paper;

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Хирургический подход к коррекции тяжелого искривления коленного сустава у детей в Танзании

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Резюме

Цель: Тяжёлое искривление коленного сустава у детей обычно требует хирургического вмешательства с использованием различных хирургических подходов. Целью данного исследования было сообщить о результатах хирургической коррекции тяжёлого смещения коленного сустава у детей, которым была проведена остеотомия бедренной и большеберцовой костей, временно зафиксированная чрескожными спицами Киршнера, в стране с низким и средним уровнем дохода с ограниченными медицинскими возможностями.

Материалы и методы: Тридцать детей (в возрасте 4–9 лет) с тяжёлым искривлением коленного сустава наблюдались и подвергались хирургическому лечению в небольшой детской больнице, расположенной в сельской глубинке Танзании. Всего было пролечено 53 деформации. В 32 коленях наблюдалась варусная деформация, а в 21 колене — вальгусная деформация. В 9 случаях была выполнена только остеотомия бедра, в 28 случаях только остеотомия большеберцовой кости, в 16 случаях комбинированная остеотомия бедра и большеберцовой кости. Фиксация была достигнута с помощью перекрещенных чрескожных спиц Киршнера и послеоперационной иммобилизации всей ноги.

Результаты: Средний предоперационный варус изменился с 40°±4 до послеоперационных 5°±6 варуса. Средний предоперационный вальгус изменился с 39°±4 до послеоперационных 8°±5 вальгуса. Осложнения включали замедленное заживление ран, повреждение кожи в месте выхода спиц Киршнера, тугоподвижность коленного сустава, недостаточную и чрезмерную коррекцию деформации. Результаты были признаны отличными в 18 случаях, хорошими в 21, удовлетворительными в 11, плохими в 3.

Заключение: Этот метод позволил нам добиться удовлетворительной коррекции тяжёлого смещения коленного сустава с помощью менее инвазивной хирургии. Недорогое оборудование, такое как спицы Киршнера, в сочетании с иммобилизацией гипсовой повязкой позволило удовлетворительно зафиксировать остеотомию и снизить общую стоимость операции, что желательно в странах с низким и средним уровнем доходов.

Ключевые слова

Болезнь Блаунта, смещение коленного сустава, смещение конечностей, остеотомия, педиатрическая помощь