Distal Femoral Osteotomy Using the LCP Pediatric Condylar 90-Degree Plate in Patients With Neuromuscular Disorders

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Background: In patients with cerebral palsy and other neuromuscular disorders, correction of a fixed knee flexion deformity is thought to be crucial for the improvement of gait. The distal femoral extension osteotomy (DFO) is one method to achieve this goal. The standard implant for fixation of the 2 fragments in DFO is the conventional AO blade plate. The aim of this study was to report the outcome of using the new LCP Pediatric Condylar 90-Degree Plate for DFO.

Methods: Thirty-eight patients undergoing 63 DFOs were included. The mean age was 16.3 ± 4.4 years (range, 4 to 27 y) at the time of surgery. Thirty-two patients had a diagnosis of cerebral palsy and 6 patients had other neuromuscular disorders including myelomeningocoele and arthrogryposis. Thirteen patients had unilateral procedures and 25 had bilateral procedures.

Results: The mean duration of the surgical intervention was 67.9 ± 26.5 minutes (range, 30 to 180 min) and the mean blood loss was 100.0 ± 42.1 mL (range, 50 to 250 mL). In 84% of the cases, large-fragment (5.0 mm) implants were used. The mean extension correction in 84% of the patients (n = 53) was 22.8 ± 10.3 degrees (range, 5 to 50 degrees). In this series, there were 2 complications in 63 osteotomies (3%). Radiologic follow-up of the cohort was until the time of plate removal (14.2 ± 4.3 mo; range, 6 to 26 mo). Three months after the index operation, all osteotomies were radiologically consolidated. At this time and at plate removal, there were no malunions or nonunions in this cohort. Clinical follow-up of the cohort was performed until the end of the study (mean 35.5 ± 6.7 mo; range, 22 to 46 mo). At the end of the study, 59 plates (94%) had been removed.

Conclusions: The new LCP Pediatric Condylar 90-Degree Plate provides stable and safe fixation of distal femoral correction osteotomies in patients with neuromuscular disorders.

Level of Evidence: Level IV.

Key Words: cerebral palsy, fixed knee flexion deformity, surgical correction, locking compression plate

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Distal or supracondylar femoral osteotomy was first described by Osgood.[1] In this paper, a method of osteotomy of the distal femur for fixed flexion of the knee joint was described. Since then, only a few publications have reported this surgical technique in patients with neuromuscular disorders. Distal femoral extension osteotomy (DFO) has also been described for the treatment of fixed flexion deformities associated with poliomyelitis, arthritic conditions, and myelomeningocele.[1–7]

DFO is a very effective osteotomy procedure to correct the distal femur in all 3 dimensions. These are flexion-extension in the sagittal plane, varus-valgus in the coronal plane, and internal and external rotation in the transverse plane. Therefore, deformities in all 3 dimensions can be corrected in 1 procedure. In patients with cerebral palsy (CP) and other neuromuscular disorders, correction of a fixed knee flexion deformity (KFD) is thought to be crucial for the improvement of gait.[8] The DFO is 1 method to achieve this goal.[8]

The standard implant for fixation of the 2 fragments in DFO is the conventional AO blade plate,[9] although other implants have been described. Locking compression plates (LCP) were first introduced in traumatology for fracture fixation.[10,11] Over the last few years, an increasing variety of similar implants using locking screw technology have been designed. The advantages of these implants are improved healing because of reduced plate to bone contact, maintaining periosteal blood supply, angular stability, and stable fixation even in osteoporotic bone.[12] The pediatric LCP hip plate was introduced in 2007 and is now in widespread use. The early results with this implant for fixing proximal femoral osteotomies in patients with CP and severe osteoporosis were published from this department.[12] The locking plate technology proved advantageous in osteoporotic bone common in these patients. Another study with this implant showed similar, encouraging results, again in patients with neurological conditions.[13] Deriving from the LCP hip plate, a modified implant with a 90-degree angle between the proximal shank of the plate and the distal screws was designed for use in the distal femur. This plate allows correction as distal as necessary in skeletally immature patients without growth plate disturbance while providing stable fixation of the distal fragment with screws. A further advantage is the possibility for preliminary, temporary fixation without large drill holes in the proximal fragment, which allows for full assessment of the osteotomy including clinical tests on the table while still allowing for fine adjustment of the position of the osteotomy before final fixation.

The aim of this study was to report the demographics, surgical details (correction angles, blood loss, duration of the surgical procedure), complications, and the radiologic and clinical results using the new LCP Pediatric Condylar 90-Degree Plate for distal femoral osteotomy in patients with neuromuscular disorders. We hypothesized that this implant can consistently achieve good results, with few complications.

METHODS

Study Design

DFO using the new LCP Pediatric Condylar 90-Degree Plate (Synthes, Switzerland) commenced in May 2007, with recruitment for this study continuing until September 2009. All DFO osteotomies using the new implant were carefully and prospectively registered in an Excel database. During this period, all patients who were seen in our department with a neuromuscular condition and who required a DFO were included in this study. Exclusion criteria were a previous distal femoral fracture, previous DFO, or other bone pathology affecting the femur at the level of the intended osteotomy. Previous hamstrings surgery and open growth plates at the distal end of the femur were not exclusion criteria.

A total of 38 patients fulfilled the eligibility requirements. The mean age was 16.3 ± 4.4 years (range, 4 to 27 y; median 14.5 y) at the time of surgery. Thirty-two patients were diagnosed with CP and 6 patients had other neuromuscular disorders including meningomyelocele and arthrogryposis. Thirteen patients had unilateral surgical procedures and 25 had bilateral procedures. Therefore, a total of 63 osteotomies were analyzed. Tables 1 and 2 illustrate the demographics and diagnoses of the cohort. Postoperatively, all patients had radiologic follow-up 6 and 12 weeks after the index operation and before plate removal (approximately 12 mo postoperative). All patients had clinical follow-up till the end of the study (end of April 2011). Full weight bearing of the operated leg was permitted in all cases after the 6-week examination.

TABLE 1. Demographics of the Cohort

Result	N
No. osteotomies	63
No. patients	38
No. bilateral	25
No. unilateral	13
No. revised	2 (3.2%)
Mean age of patients	16.3 y (± 4.4 SD; range, 4-27 y)
No. patients with previous hamstring release	7 bilateral (14 knees) 1 unilateral (1 knee)

TABLE 2. Diagnosis of the Cohort

Diagnosis	No. Patients (N = 38)
CP	32 (84.2%)
Hemiplegic CP	1
Diplegic CP	15
Tetraplegic CP	16
Others	6 (15.8%)
Meningomyelocele	3
Arthrogryposis	1
Incomplete paraplegia	1
Postpolio syndrome	1

CP indicates cerebral palsy.

Surgical Technique

Before the procedure, the deformity was clinically and radiologically assessed. This included long leg coronal assessment of the varus/valgus angulation at the knee both clinically and radiologically. The anteversion of the femoral neck was assessed clinically and with Dunn-Ripstein views of the pelvis. The fixed flexion deformity of the knee was assessed clinically and with the aid of lateral knee radiographs taken with the knee in maximal extension. Surgery was performed under general anesthesia and intravenous antibiotics were routinely administered when the operation started. The angular correction was checked under anesthesia before skin preparation and draping. The surgery was performed by a lateral approach to the distal femur, elevating the vastus lateralis muscle supraperiosteally from the lateral aspect of the bone. The plate was then positioned distally with the distal screw as close to the growth plate as possible using the plate itself as a seating device for the guide wires. In mature patients with closed growth plates, the placement of the plate did not differ, because the plate always fits very well to the lateral condyle of the distal femur. Correction of extension was achieved by directing the plate parallel to the tibial axis when the knee was held in maximal extension. Figure 1 shows the intraoperative positioning of the plate. This technique allowed complete correction of the KFD once the plate was fixed. The plate was then removed after marking the level of the osteotomy. Two positional Kirschner wires were inserted anterior to control rotation, and the internal/external rotation balance was checked in all cases clinically before skin closure. The periosteum was opened only at the osteotomy site and the osteotomy was performed cutting out a full wedge. The plate was placed back and fixed distally with 3 bicortical locking screws. The proximal fragment was now reduced to the plate and preliminarily fixed with 2 wires and a reduction clamp. The position of the osteotomy was checked clinically in all 3 dimensions and by an image intensifier in anteroposterior and lateral views. Correction of rotation required removal of the proximal wires and rereduction of the osteotomy. Flexion/extension could be corrected by leaving 1 wire in place and angulating the osteotomy in the desired direction (the plate was then slightly oblique in respect of the

FIGURE 1. Intraoperative positioning of the plate. The plate needs to be placed parallel to the anterior border of the tibia to achieve full extension of the knee joint.

femur) and varus/valgus by medialization or lateralization of the proximal fragment with respect to the plate, sometimes requiring a small gap between the plate and the bone, particularly if length had been removed from the femur. After a satisfactory position was reached, the plate was secured with 3 proximal locking bicortical screws. The wound was closed without drains, dressed, and an extension knee brace was applied. Patients were subjected to standard inpatient and outpatient postoperative rehabilitation regimens including intensive passive and active physiotherapy of the knee directed at attaining optimization of gait.

Consent and Ethical Approval

All patients/parents gave written consent for the procedure and the use of the new plate. The study was performed according to the declaration of Helsinki (World Medical Association).

Data Collection

Data were collected prospectively in an Excel database and expressed as percentage and means with SDs where applicable.

RESULTS

Surgical Details

The mean duration of the surgical intervention was 67.9 ± 26.5 minutes (range, 30 to 180) and the mean blood loss was 100.0 ± 42.1 mL (range, 50 to 250 mL). In 84% of the cases, large-fragment (5.0 mm) implants were used. The extension correction data were available for 84% of the osteotomies (n = 53) and the mean was 22.8 ± 10.3 degrees (range, 5 to 50 degrees). In the remaining 16% of the osteotomies (n = 10), an isolated correction of the rotation was performed. Table 3 presents the intraoperative data.

TABLE 3. Intraoperative Data

No. Osteotomies	N (Total = 63)
Implant size	
3.5 mm	N = 10 (16%)
5.0 mm	N = 53 (84%)
Extension	N = 53 (84%) femora had extension carried out
Mean extension correction (deg.)	22.8 ± 10.3 degrees (range, 5-50 degrees)
Rotational correction	N = 49 (78%) femora had rotational correction carried out N = 37 (59%) had correction into external rotation N = 12 (19%) had correction into internal rotation
Mean external rotation correction	20.1 ± 9.0 degrees (range, 5-50 degrees)
Mean internal rotation correction	17.5 ± 7.2 degrees (range, 10-30 degrees)
Varus/valgus correction	N = 7 (11%) femora had varus corrections carried out, 4 with 10 degrees and 3 with 5 degrees of correction. Mean 7.9 ± 2.7 degrees N = 5 (8%) femora had 5 degrees of valgus correction carried out
Shortening	N = 5 (8%) femora had the femur shortened, 4 shortened by 0.5 cm and 1 by 1 cm
Blood loss (mean, mL)	100 ± 42.1 (range, 50-250)
Operation time (min)	67.9 ± 26.5 (range, 30-180)

± are standard deviations

Concomitant Operations and Complications

In this series, there were 2 complications in 63 osteotomies (3%). In 1 femur, the fixation failed at 2 weeks postoperatively, thought to be due to severe spasm in a 16-year-old boy with spastic diplegia. This required revision and the same design of implant but longer and had more proximal screw holes, providing increased stability. This patient subsequently did well. In another patient, 1 screw was found to have backed out of its locked threads at the 6-week postoperative follow-up. Revision entailed simple exchange of this screw, securely locked in place. There were no infections in this cohort. A total of 90 concomitant procedures were carried out in conjunction with the DFO. Tables 4 and 5 summarize the outcome data.

Radiologic and Clinical Results

There was no loss of correction at any time in any case, except in the 1 patient with implant failure (described under complications above). Radiologic follow-up continued until the time of plate removal (14.2 ± 4.3 mo; range, 6 to 26 mo). At the 12-week follow-up, all osteotomies were radiologically consolidated in this cohort.

TABLE 4. Outcome Data

Complications	In 1 femur, the fixation failed and required revision In 1 femur, 1 screw was noted to be slightly loose. Simple exchange of the screw 6 weeks after index operation
Length of clinical follow-up (mo)	Mean, 35.5 ± 6.7 (range, 22-46)
Metal removed	N = 59 (94%) femora the plate was removed Mean time to removal = 14.2 ± 4.3 mo (range, 6-26 mo), with radiologic follow-up

TABLE 5. Procedures Performed at the Same Time as the Distal Femoral Osteotomy

Concomitant Operation	No. Legs, N (as a Percentage of 63 Femora)
PTS	42 (67%)
TAL	13 (21%)
Calcaneus lengthening (+/−) CC arthrodesis	12 (19%)
Hamstring release	7 (11%)
Tibialis posterior lengthening	4 (6%)
Tibialis anterior shortening	4 (6%)
Patella fixation (ORIF)	3 (5%)
Pelvic osteotomy	1 (2%)
Tibial osteotomy (supramalleolar)	2 (3%)
Recorded as SEMLS	2 (3%)
Bilateral: PTS and Baumann procedure	
Bilateral: PTS and tibialis posterior lengthening	

CC indicates calcaneocuboid joint; ORIF, open reduction internal fixation; PTS, patella tendon shortening; SEMLS, single-event multilevel surgery; TAL, tendon achilles lengthening.

At this time and at plate removal (at a mean of 14.2 mo after the index procedure), there were no malunions or nonunions. Figure 2 demonstrates a typical case showing the radiographs preoperatively and 1 year postoperatively after DFO using the new implant. Clinical follow-up of the cohort was performed until the end of the study (mean 35.5 ± 6.7 mo; range, 22 to 46 mo). In all cases, full passive knee extension was achievable at the last follow-up examination. No valgus or varus deformities were observed clinically. At the end of the study, 59 plates (94%) had been removed.

DISCUSSION

Knee dysfunction in children with CP is a very common problem, and a wide range of surgical procedures have been described for its management.[8] If KFD is more than 5 to 10 degrees, distal hamstring lengthening on its own is mostly ineffective.[8] There is also a risk of complications such as common peroneal nerve stretch injuries and it may increase anterior pelvic tilt.[14,15] Correction of KFD by supracondylar extension osteotomy (SEO) in combination with patellar tendon shortening (PTS) is more effective.[9]

Our indications for SEO-PTS include KFD of 10 to 50 degrees, severe crouch gait, an extensor lag > 10 degrees, and patella alta on lateral knee radiographs. The results of the new LCP Pediatric Condylar 90-Degree Plate for DFO including its use for SEO have not yet been reported. If the KFD is more than 30 degrees, our routine management includes performing a single tenotomy of the semitendinosus tendon 3 months before the SEO-PTS procedure. After the semitendinous tenotomy, an extension orthoses is applied to the knee to minimize the KFD as much as possible preoperatively. This is accompanied by an intensive physiotherapist-directed stretching and muscle strengthening regimen. During this period, the

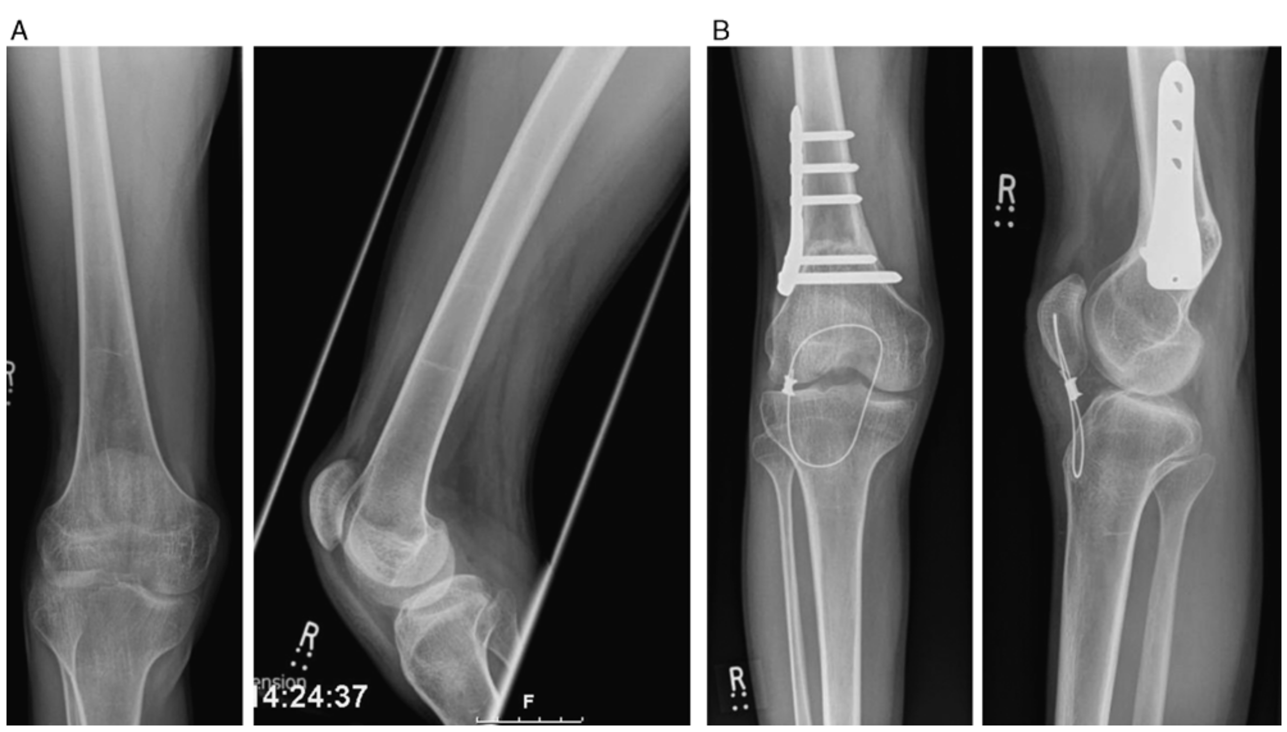

FIGURE 2. Case report: radiographs preoperatively and 1 year postoperatively after distal femoral extension osteotomy using the new implant. A, Preoperative radiographs of a 20-year old man with spastic quadriplegia, Gross Motor Classification System level II, fixed knee flexion contraction of 40 degrees and patella alta. B, Radiologic results 1 year after supracondylar extension osteotomy (40 degrees of extension and 10 degrees of external rotation) in combination with patellar tendon shortening using a cable wire.

requirement for concomitant surgery is defined and most of the patients with an SEO have this as part of a single-event multilevel surgery. Before any muscle-tendon–lengthening procedures in our department, all patients are tested with a preoperative botulinum toxin test injection to ensure that the surgery will not result in undue weakening and compromise the efficiency of gait.[16] We perform this test at all anatomic levels where muscle-tendon lengthening is planned, in particular before tendon Achilles lengthening.[17] When we are satisfied that these pre–single-event multilevel surgery checks are complete, the SEO-PTS procedure is performed. We believe that this preoperative regimen is necessary to avoid hyperextension of the knee joint postoperatively, a complication that would be devastating in terms of gait function. In 1 recent well-designed study, however, Healy et al[18] showed that simultaneous hamstring lengthening is not necessary when performing DFO and patellar tendon advancement.

Stout et al[19] retrospectively reviewed their outcomes after isolated distal femoral osteotomy versus isolated patellar tendon advancement versus a combination of both distal femoral osteotomy and patellar tendon advancement. The combined procedure showed the most favorable outcomes, with maximum improvement of extensor lag (14 degrees) and of postoperative kinematic measurements (ie, 16 degrees' improvement of knee flexion at initial contact and 29 degrees' improvement in minimum knee flexion during the stance phase). This study recommended the combination of DFO with patellar tendon advancement for significant KFD. For fixation of the SEO in this study, the surgeons used a conventional AO blade plate.[9]

Limitations of the AO blade plate include the lack of fine tuning and versatility. It does not allow any changes in the position of the implant after the initial insertion of the seating chisel. From this point of view, it is an implant where there is only "one chance to get it right." In contrast, the new LCP plate described here allows for preliminary fixation of the proximal fragment with 2 wires and a reduction clamp and the opportunity to adjust and fine tune the positioning of the implant and therefore the correction in all 3 planes as described in the surgical technique.

It is our opinion that the new LCP Pediatric Condylar 90-Degree Plate is the ideal implant for DFO, and the results demonstrated here reveal the plate to provide a lasting correction of KFD. Of course, not only the implant is important, other factors like the postoperative treatment and rehabilitation with regular physiotherapy or orthotics are crucial as well. But it is a powerful implant, allowing the osteotomy to be performed as distally as possible without growth plate disturbance, and correction in all 3 dimensions is easily achievable. Previously, commonly used implants have resulted in more proximal fixation due to difficulties in achieving sound distal fixation and have thus compromised the ability to achieve the necessary correction.

In our series, the complication rate (3%) was very low and equivalent to or less than other reported series.[9,14,15,19–21] Only 2 of them[9,19] have reported the isolated surgical results of DFO, but no details on the surgical angles of corrections have been provided. Stout et al[19] reported a total complication rate associated with the distal femoral extension osteotomies of 19% (9 of 49), which was higher than that in our series. The mean duration of the operative procedure was 68 minutes and the average blood loss was 100 mL. No infections or nonunions were observed. The limitations of this study are the relatively small number of surgical interventions performed and the lack of a control group. There was no radiologic follow-up after plate removal, which was an average of 14 months after the index procedure. However, the clinical follow-up of the cohort was approximately 3 years and no recurrences of KFD were seen in any patient.

SUMMARY

(a) The new LCP Pediatric Condylar 90-Degree Plate provides stable and safe fixation of distal femoral correction osteotomies in patients with neuromuscular disorders. It can correct the distal femur in all 3 dimensions.
(b) The operative time is quick, the blood loss is minor, and the complication rate is low.
(c) Early full weight bearing can be safely allowed at 6 weeks after the index procedure and, in cases without concomitant soft tissue operations, can be allowed immediately postoperatively.

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