



Functional and Radiological outcomes after Surgical Management of Crouch Gait in Spastic Diplegic Cerebral Palsy: A Prospective Cohort Study

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Abstract

Background: Crouch gait—walking with excessive knee bend during stance—is a common, disabling pattern in children with spastic diplegic cerebral palsy. It raises the effort of walking, causes knee pain, and limits participation. Restoring a more extended knee during stance often requires both bony correction and improvement of the extensor mechanism.

Methods and materials: We treated ambulatory children with severe crouch using a tailored combination of distal femoral extension osteotomy (DFEO) and patellar tendon advancement (PTA), adding selective soft-tissue releases when needed. Preoperative assessment included clinical measures (popliteal angle, extensor lag), functional scoring, and knee radiographs to measure patellar height. Surgery used growth-respecting fixation in immature patients and standardized postoperative immobilization and rehabilitation.

Results: Patients showed improved knee extension on exam, lower patellar-height indices on radiographs, better short-distance walking scores, and less anterior knee pain. Osteotomies healed without major complications and patients progressed through rehabilitation to better function.

Conclusion: When crouch is caused by fixed knee flexion and extensor mechanism insufficiency, combining DFEO with PTA—and following it with disciplined physiotherapy and orthotic support—produced reliable short-term gains in alignment, pain, and walking ability in this series.

Keywords: Crouch gait, Cerebral palsy, Distal femoral extension osteotomy, Patellar tendon advancement, Functional Mobility Scale

Introduction

Cerebral palsy is a lifelong disorder of movement and posture originating from early brain injury and frequently leads to secondary musculoskeletal problems [1]. Clinicians use the Gross Motor Function Classification System (GMFCS) to describe a child's mobility and to help plan treatment [2]. Among the gait patterns seen in diplegic cerebral palsy, crouch

gait—marked by persistently increased knee flexion during stance—stands out for its negative impact on energy cost, pain, and independence [3].

Crouch usually develops or worsens during growth spurts, when weak antigravity muscles and evolving soft-tissue tightness fail to maintain an upright gait pattern [4]. The causes are multiple and often act together: shortened or spastic



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hamstrings, weak quadriceps with patella alta and extensor lag, torsional femoral abnormalities, fixed knee flexion contractures, and foot deformities. Each element must be assessed carefully before planning surgery [5]. While instrumented gait analysis offers precise data, many centers rely on clinical measures—popliteal angle, extensor lag, and patellar-height ratios—together with validated function scales to guide treatment [6].

The modern approach favors single-event multilevel surgery (SEMLS) when multiple deformities contribute to poor gait, because tackling relevant problems at once can reduce repeated operations and speed rehabilitation [7]. For older children and adolescents with a fixed crouch and clear extensor-mechanism dysfunction, combining distal femoral extension osteotomy (DFEO) to correct bony alignment with patellar tendon advancement (PTA) to restore quadriceps mechanics addresses the two main pathologies that maintain crouch. This study describes our experience with that combined strategy and its short-term outcomes.

Materials and Methods

We reviewed consecutive ambulatory patients under 18 years with spastic diplegic cerebral palsy and clinical crouch treated between October 2019 and October 2021. Inclusion required functional ambulation with GMFCS II–IV and clinical evidence of fixed knee flexion and/or patella alta with extensor lag. Patients who were non-ambulant (GMFCS V) or medically unfit for surgery were excluded. Institutional approval and informed guardian consent were obtained [8].

Before surgery every child had a focused history and standardized exam: measurement of popliteal angle, passive knee range of motion, extensor lag, hamstring and gastrocnemius tightness, and spasticity grading (Modified Ashworth, Tardieu). Functional mobility was recorded using the Functional Mobility Scale (5, 50, 500 m) and GMFCS to establish baseline capacity. Plain AP and lateral knee radiographs were used to measure patellar height (Koshino and Insall–Salvati indices) and to plan the need for PTA [9, 10].

Surgical planning was individualized. DFEO was performed through a lateral approach using a wedge or V-shaped osteotomy fixed with pediatric condylar locking plates; care was taken to protect the distal femoral physis in skeletally immature patients. PTA was achieved by advancing the patellar tendon with either a periosteal flap or bone-block technique depending on skeletal maturity. Additional soft-tissue procedures—hamstring fractional lengthening, gastrocnemius recession, patellar plication, or rectus femoris procedures—were added selectively when clinical assessment indicated their benefit [4]. Postoperatively patients had an above-knee cast or long knee brace for about six weeks, radiographs at follow-up intervals, staged weight bearing after immobilization, orthoses as needed, and a structured physiotherapy program emphasizing knee-extension control, quadriceps strengthening, and gait re-

training. Data were recorded prospectively when possible; paired comparisons assessed pre- and postoperative changes with significance set at $p < 0.05$ [11, 12].

Results

The study group comprised 16 patients (14 boys, 2 girls) with a mean age of 11.6 ± 3.5 years (range 5–17), most classified as GMFCS III (14 patients) and ambulant with assistance (15 of 16). All patients underwent distal femoral extension osteotomy combined with patellar tendon advancement, with selective soft-tissue procedures added as needed (hamstring release in 11 patients, gastrocnemius/gastro soleus release in 2, patellar plication in 9; bilateral supracondylar extension osteotomy in 14, bilateral varus-derotation osteotomy in 2). Fixed knee-flexion deformity improved from a preoperative mean of $\approx 36^\circ$ (right $37.5^\circ \pm 3.1$, left $35.9^\circ \pm 3.7$) to about 1° (right $1.56^\circ \pm 2.3$, left $0.63^\circ \pm 1.7$). The popliteal angle fell markedly (overall from roughly 61° to 28.4°), and lateral radiographs showed correction of patella alta with Koshino index improving from 1.45 ± 0.06 to 1.27 ± 0.05 and Insall–Salvati ratio from 1.36 ± 0.06 to 1.05 ± 0.03 . Functional Mobility Scale scores rose at short distances—5 m from 3.0 to 4.0, and 50 m from 2.06 to 3.06—while 500 m remained unchanged at 2.0. At a minimum follow-up of 12 months (radiographs at 1 month, 6 months, and 1 year), most families reported less anterior knee pain and easier transfers; there were no major intraoperative complications, all osteotomies united uneventfully, hardware remained stable, and only minor transient postoperative issues were seen that resolved with conservative care and rehabilitation.

Discussion

Our experience supports the idea that fixing crouch often requires correcting more than one problem at the same time. DFEO straightens a fixed knee-flexion deformity, while PTA brings the patella and tendon into a better mechanical position so the quadriceps can work more efficiently. When both issues coexist, treating only one may leave a residual gait problem [11, 13].

Stable fixation that protects growth plates is crucial in children; locking plates offer secure correction and allow the team to start rehabilitation sooner [15]. Adding selective soft-tissue releases—hamstring or gastrocnemius lengthening, patellar plication, or muscle transfers—depends on the child's specific contractures and motor control, and tailoring these choices improves outcomes [16, 17, 18]. Non-surgical adjuncts such as orthoses, functional electrical stimulation, or targeted botulinum toxin injections can also help before or after surgery, depending on the underlying deficits [12, 9].

This study's limitations include the small cohort size, single-center design, and lack of instrumented gait laboratory data to quantify kinematic change precisely. These caveats mean that while early clinical and radiographic improvements are encouraging, long-term follow-up with objective gait analysis

would better define durability and any secondary changes at the hip or pelvis [14, 20]. Nonetheless, the consistent improvements seen here align with other series that report good short-term gains when DFEO and PTA are combined in appropriate patients [13, 15].

Clinical implications

When a child with diplegic cerebral palsy walks in crouch because of a fixed knee-flexion deformity combined with patella alta and quadriceps inefficiency, a planned combined operation that corrects the bone alignment and the extensor mechanism—followed by disciplined rehabilitation and orthotic support—can produce meaningful improvements in pain and function. Preoperative planning should use simple, reliable clinical measures and patellar-height indices to decide which components require correction. Respecting growth plates, ensuring stable fixation, and engaging a multi-disciplinary team are essential to turn anatomic correction into better every day walking.

Conclusion

In this series, combining distal femoral extension osteotomy with patellar tendon advancement in selected ambulatory children and adolescents with spastic diplegic cerebral palsy and severe crouch gait produced reliable short-term improvements in knee alignment, patellar height, pain, and walking ability. The operation is safe when surgical technique protects the growth plate and when a coordinated postoperative program of immobilization, orthotic support, and physiotherapy is followed. Larger studies with gait laboratory follow-up are needed to confirm how long these benefits last and to refine which adjunct procedures give the best long-term results.

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