SUPRA CONDYLAR FEMORAL EXTENSION OSTEOTOMY WITH PATELLAR TENDON ADVANCEMENT TO TREAT FIXED KNEE FLEXION DEFORMITY IN CROUCHING AMBULATORY ADOLESCENTS WITH CEREBRAL PALSY

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ABSTRACT

Background: Ambulatory cerebral palsy (CP) patients present with different gait patterns because of muscular spasticity and contractures and subsequent limited range of motion leading to loss of their functional abilities. Crouch gait is one of the most common gait pattern in ambulatory children with CP.

Aim of the work: The purpose of this study is to evaluate the results of supra condylar femoral extension osteotomy (SCFEO) and patellar tendon advancement (PTA) in the treatment of fixed knee flexion deformity (FKFD) in patients with spastic ambulatory cerebral palsy (CP) to achieve full knee extension and restore an appropriate relationship between quadriceps length and tension in order to maintain knee extension during the stance phase of gait to correct the crouch gait.

Patient and Methods: This prospective case series study was done on 20 patients (37 knees); 12 males and 8 females, who had spastic or mixed (mainly spastic) CP and walked with a crouch gait, and who underwent combined SCFEO and PTA along with the context of single event multi-level surgery.

Results: The mean Fixed Knee Flexion Angle (FKFA) improved from 24.25° ±11.86° to be 2.25°± 2.25°. The mean knee extension lag improved from 15.8°±5.68° to be 4.2°±1.31°. The mean Gross Motor Function Measurement (GMFM) improved from 53.3 to be 69.1. The mean Koshino Index (KI) improved from 1.54±0.29 to be 1.14±0.12.

Conclusion: For crouching adolescents there are 4 questions must be answered: Frist, differentiate between isolated myogenic flexion deformity and combined myogenic-arthrogenic knee flexion deformity. Second, assess isolated myogenic flexion deformity due to hamstring shortening by unilateral popliteal angle test. Third, differentiate between apparent and true hamstring shortening by popliteal shift test; apparent functional hamstring shortening and hamstring lengthening is not indicated. Forth, if the unilateral popliteal angle is positive with negative popliteal shift test, true hamstring shortening is found.

Keywords: Ambulatory cerebral palsy, fixed knee flexion deformity, Supra condylar femoral extension osteotomy, Patellar tendon advancement.

INTRODUCTION:

Ambulatory cerebral palsy (CP) patients present with different gait patterns because of muscular spasticity and contractures and subsequent limited range of motion leading to loss of their functional abilities. Crouch gait is one of...
the most common gait pattern in ambulatory children with CP and is contributed to many factors\(^{(1)}\).

Rodda et al., described crouch gait as, knee flexion during the stance larger than 20°. The ankle is excessively dorsiflexed and the hip is excessively flexed during stance. The pelvis is in the normal range or tilted posteriorly\(^{(2)}\).

Crouch gait often develops and rapidly progresses around the time of the pubertal growth spurt. The development of musculo-oskeletal deformities, collectively referred to as lever arm deformities. The deformities that are frequently seen in adolescents with spastic diplegia are excessive femoral ante version, hip subluxation, patella alta, excessive external tibial torsion, and pes valgus (termed lever arm deformities)\(^{(3)}\).

Once a crouch gait has developed, the body mechanics lead to the progression of knee flexion, hip flexion, and ankle dorsiflexion. The loss of an adequate plantar flexion/knee extension couple maintains the ground reaction force behind the knee joint and in front of the hip and ankle joints. Fixed knee-flexion contra-ctures often develop. Patellar tendon elongation and patella alta develop over time and become contributing factors. Knee and back pain have been mentioned as two of the primary factors that limit the walking ability of these patients\(^{(4)}\).

Several methods are described in the literature for treatment of fixed knee flexion deformity (FKFD) in CP patients, such as hamstring lengthening, posterior knee capsulotomy and serial casting. Complications such as neurovascular injuries, femoral fractures, skin break-down, recurrence and hyperextension are more often presented with severe deformities. Supra condylar femoral extension osteotomy (SCFEO) has been considered as an alternative to posterior knee capsulotomy for cases in which total extension was not achieved after the soft tissue release\(^{(5)}\).

SCFEO was originally described by Osgood in 1913 and has since been variously reported for the treatment of fixed flexion deformities associated with poliomyelitis, myelomeningocele and arthritis\(^{(6)}\).

Patellar tendon advancement (PTA) was originally described by Chandler in 1933 and a modified technique was described by Roberts et al\(^{(7)}\).

Combined SCFEO and PTA have encouraging results regarding pain relief and improvement in community walking levels\(^{(4)}\).

**AIM OF THE WORK:**

The purpose of this study is to evaluate the results of supra condylar femoral extension osteotomy (SCFEO) and patellar tendon advancement (PTA) in the treatment of fixed knee flexion deformity (FKFD) in patients with spastic ambulatory cerebral palsy (CP) to achieve full knee extension and restore an appropriate relationship between quadriceps length and tension in order to maintain knee extension during the stance phase of gait to correct the crouch gait.

**PATIENT AND METHODS:**

**Demographics:**

This prospective case series study was done on 20 patients (37 knees); 12 males and 8 females, who had spastic or mixed (mainly spastic) CP and walked with a crouch gait, and who underwent combined SCFEO and PTA along with the context of SEMLS. Their mean age at the time of surgery was 12.50 years (range, 10 to 17 years), the preoperative Gross Motor Function Classification System (GMFCS) was III in
Supra condylar femoral extension osteotomy with patellar tendon advancement to treat fixed knee.

17 Patients, and II in 3 patients and the mean follow up was 2 years (range 1.5-2.5 years). The study was conducted in Ain Shams University hospitals in the period between March 2016 and September 2018.

- **Inclusion criteria:**
  2. Ambulatory adolescents with spastic or mixed hypertonia pattern with predominant spasticity.
  3. GMFCS level II- III.
  5. Fixed knee flexion deformity of 10° or higher.

- **Exclusion criteria:**
  1. Other progressive neuromuscular disorder.
  2. Isolated myogenic knee flexion by examination.
  3. Flexion contractures of >40°.
  4. Non communicable patients.
  5. Expected non-compliance or no access to facilities of physiotherapy and rehabilitation.

All patients had been given informed consent, and the study protocol was approved by the Institutional Review Board in our university.

Of the 20 patients, involving 37 limbs in twenty cerebral palsy children with crouch gait pattern. All patients had fixed knee flexion deformity and underwent distal femoral extension osteotomy. All patients had concomitant extensor mechanism tightening. All except three patients had bilateral procedures.

The 20 patients were classified according to the expanded and revised GMFCS for children and youth with CP. Three (15%) were GMFCS II and seventeen (85%) were GMFCS III (Diag. 1). All patients have had bilateral spastic or mixed (mainly spastic) diplegic CP.

Diag. 1: Pie chart showing the preoperative distribution of GMFCS in the study group.

**Methods:**

**Preoperative evaluation:** Patients were evaluated by the following:

**History:**

History taking emphasized on, but not limited to, the following points:

- Any recent deterioration of patient activities and anterior knee pain.
- Previous physiotherapy.
- Previous interventions: Most of the patients had previous interventions, either surgery or Botox (BTX) injection, especially of the calf muscles.

**Clinical examination:**

Standard couch examination of each patient was done. Goniometric measure-
ments of joint range of motion and deformities were done, the same way as standards for these examinations. The most important points in physical examination include, but not limited to, the following:

- **Hip examination**:
  - Fixed flexion deformity at the hip by Thomas test.
  - Hip range of motion mainly:
    - Abduction in extension and flexion for adductor ± gracilis contracture.
  - Internal and external rotation, (for femoral anteverision) were measured with the patient prone.

- **Knee examination**:
  - Fixed flexion deformity at the knee:
    - The supine forced knee extension test (with the hips extended) differentiates between isolated myogenic knee flexion deformity and combined myogenic–arthrogenic FKFD (Diag. 2).

  ![Diag. 2: The knee deformity assessment and management algorithm.](image)

- **Ankle and foot examination**:
  - Measurement of gastrocnemius and soleus length with the use of Silfverskiöld test.
  - Tibial torsion: It was measured with the Trans Malleolar Axis method.
  - Ankle varus or valgus deformity.

**Observational gait analysis**:

Patient was exposed from the foot to the umbilicus leaving underwear rolled to uncover the ASIS anteriorly and PSIS posteriorly. Patient was asked to walk several times along a small corridor and the examiner seated with his eyes at the same level as the patient knees (middle of lower limb). This was done from front and side. Video recording was sometimes done, after consenting, to be visualized several times and in slow motion for more analysis in complex cases.

**Evaluation of the existing function and functional needs of the child by GMFM score**:

The Gross Motor Function Measure-88 (GMFM-88) is a standardized observational instrument used to assess motor capacity in CP patients preoperatively and at one year postoperatively.
Supra condylar femoral extension osteotomy with patellar tendon advancement to treat fixed knee.

Radiography:
- X-ray pelvis AP in neutral hip rotation and frog lateral: two views of the hips were taken for the patients to exclude any hip subluxation or dislocation.
- X-ray both knees AP and dead lateral: dead lateral view was done in knee flexion from 30° to 90° and Koshino index (Fig. 1) was calculated to assess the patellar height\(^\text{10}\).

Fig. 1: Lateral knee X-ray of case 8 illustrating Koshino index.

Operative components:

Anaesthesia: General anaesthesia was used for all patients.

Positioning:
Supine position allows access for both extension osteotomy and patellar advancement. The procedures are performed under tourniquet control.

Operative technique:

Approach:
- The extension osteotomy of the distal femur is performed via a lateral distal femoral incision.
- The patellar advancement is performed through a direct anterior incision centered over the tibial tubercle.

Supra condylar femoral extension osteotomy:
- The distal femoral physis is located with the aid of fluoroscopy.
- A 4- to 5-cm longitudinal incision is made laterally, with the distal end of the incision at the level of the physis. A subvastus approach is made to the distal femur after incising the iliotibial band. This is most easily accomplished in a distal-to-proximal direction using electrocautery to mobilize the vastus off the intermuscular septum.
- Fluoroscopic imaging is used to localize the osteotomy site (generally 2.5 cm proximal to the distal femoral physis). The increased healing capacity and increased cross-sectional area in the metaphysis relative to the diaphysis make it very important to perform a metaphyseal osteotomy.
- The level of osteotomy was marked with a saw blade. Another vertical mark is used to mark rotation. The distal osteotomy is performed first. The second osteotomy is performed perpendicular to the femoral shaft, typically meeting the
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first osteotomy at the posterior cortex (although with more severe deformities, a cuneiform wedge including several millimeters of posterior cortex may also be removed to avoid neurovascular stretch) (Fig. 2).

Fig. 2: intraoperative first and second osteotomy

- A large elevator may be used to protect the posterior structures during the osteotomy.
- The anterior wedge of bone is removed.
- The posterior edge of the distal fragment was trimmed to avoid vascular injury.
- The osteotomy was fixed with plate and screws or crossing K-wires depending on the age of the patient and the circumference of the femur (Diag. 3).
- Fixation by smooth K-wires in a crossed configuration. Three pins are usually all that is needed for most children, though two pins are likely to be biomechanically sufficient in many children.

![Pie chart showing fixation method distribution](image)

Diag. 3: Pie chart Fixation method distribution of the study group by k-wires (35.1%), and plate and screws (64.9%) of fixation method.

- Fixation by plate, (in our study we use locked proximal humeral plate) (Fig. 3).

![Locked proximal humeral plate](image)

Fig. 3: Shows the locked proximal humeral plate.
The plate is positioned in the lateral metaphysis with the shaft of the plate parallel to the shin of the tibia and the distal most edge is just 2-3 mm above the marked physis. According to osteotomy rule 2, the distal fragment must extend and translate posteriorly to realign the mechanical axis. If rotation is planned, the sequence of rotation, translation then angulation is respected to avoid jamming at the osteotomy (Fig. 4).

![Image](image_url)

**Fig. 4:** An anterior based wedge removed with or without femoral shortening with posterior translation of distal fragment.

- Any significant posterior bone prominence should be resected with the oscillating saw.
- The wound is closed in layers.

**Extensor mechanism tightening by PTA:**

- Done in all cases using Gillette children's hospital technique.\(^\text{12}\)
- The patellar tendon is advanced without violating its insertion.
- A T-shaped periosteal incision is made distal to the tibial tubercle apophysis.
- Medial and lateral flaps of periosteum are elevated.
- The tendon is separated from the cartilaginous tibial tubercle apophysis using a fresh scalpel, care must be taken to maintain an adequate thickness of tendon (about 2 mm) without defects.
- The next step is placement of a tension band from the patella to the tibia to protect the repair by a nylon tape suture passed by an ACL guide. Sutures are passed along the edges of the patella via a subcutaneous tunnel to the anterior incision (Fig. 5).
- The patella is advanced distally by tensioning the nylon tape until the inferior pole of the patella is at the femoral-tibial joint line, at which point the knot in the nylon tape is tied.
- Two Krackow stitches are placed in the patellar tendon, one medially and one laterally, using Ethibond suture.
- These sutures are tied deeply under the periosteal flaps (Fig. 6).
- The periosteal flaps are then sewn over the patellar tendon (Fig. 7).
- The wound is closed in routine fashion.

![Image](image_url)

**Fig. 5:** Naylon tape placed transversely across patella
Other associated operations were done to correct associated deformities found in the patient lower limbs.

**Postoperative components:**

1) **Postoperative management:**
   - All patients had high above knee cast placed at the time of surgery.
   - Anteroposterior and lateral radiographs were done to confirm proper alignment.

2) **Postoperative follow up:**
   - Patients were reviewed at 2 weeks postoperatively.
   - The osteotomies were followed up by serial X-rays till complete healing.
   - Six weeks after surgery cast is removed after complete healing of the osteotomy site.
   - Postoperative rehabilitation program involves strengthening exercises of the upper limbs and to the unfixed Joints (e.g. hips, toes) as tolerated even before removal of the lower limbs cast.
   - An intensive rehabilitation program starts at the earliest radiological evidence of satisfactory callus formation (6-8 weeks). It is prescribed as 5 times/week for six consecutive months for four hours/session. The physiotherapy training is fashioned individually for each child based on his/her functional capacity.
     - Immediately after removing the cast, a custom-made knee immobilizers are used to achieve early weight bearing exercises. The ground reaction ankle foot orthosis (GRAFO) is used in patients with weak quadriceps or weak triceps surae to prevent recurring of crouch gait.
     - Patients were followed-up by multidisciplinary team at the 6th week, the 12th weeks then every six months till the final follow up. The mean follow up was 2 (range 1.5-2.5) years.

3) **Postoperative evaluation:**
   - Fixed knee flexion angle.
   - Extension lag angle.
   - Koshino index.
   - GMFM score.

   Those parameters were also re-evaluated after one year postoperatively.
**Statistical analysis:**

Recorded data were analyzed using the statistical package for social sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean± standard deviation (SD). Qualitative data were expressed as frequency and percentage.

**The following tests were done:**

- Paired sample t-test of significance was used when comparing between related samples.
- Chi-square (χ²) test of significance was used in order to compare proportions between qualitative parameters.
- The confidence interval was set to 95% and the margin of error accepted was set to 5%.

**RESULTS**

**Statistical analysis:**

All parameters were measured preoperatively and at 1 year postoperative. The mean operative time of the supra condylar femoral extension osteotomy and patellar tendon advancement was 60±30 minutes (range, 30 to 180). The mean blood loss was 100 mL (range, 50 to 300mL).

[A] **Clinical results:**

(1) **Fixed Knee Flexion Angle (FKFA):**

At the one year follow up, the mean FKFA was 2.25°± 2.25° (range 0-15) that is compared with the mean preoperative FKFA of 24.25° ±11.86° (range 15-40) (Table 1).

Table (1): The extent of the difference over the periods through FKFA in the study group.

<table>
<thead>
<tr>
<th>Period</th>
<th>FKFA</th>
<th>Paired Sample t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Diff.</td>
<td>Delta change</td>
</tr>
<tr>
<td>Pre-operative</td>
<td>24.25±11.86</td>
<td></td>
</tr>
<tr>
<td>Post-operative</td>
<td>7.68±3.19</td>
<td>-16.57</td>
</tr>
<tr>
<td>After 1 year</td>
<td>2.25±2.25</td>
<td>-22</td>
</tr>
</tbody>
</table>

Postoperative and after 1 year (t= 5.313, with p-value <0.001**)

This table shows highly statistically significant decrease mean of postoperative and after 1 year compared to preoperative according to FKFA.

(2) **Extension Lag Angle:**

The mean knee extension lag at the one year follow up was 4.2°±1.31° (range 5-25) compared with mean preoperative knee extension lag of 15.8°±5.68° (range 15-30) (Table 2).

Table (2): The extent of the difference over the periods through extension lag angle in the study group.

<table>
<thead>
<tr>
<th>Period</th>
<th>Extension lag angle</th>
<th>Paired Sample t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Diff.</td>
<td>Delta change</td>
</tr>
<tr>
<td>Pre-operative</td>
<td>15.79±5.68</td>
<td></td>
</tr>
<tr>
<td>Post-operative</td>
<td>8.19±3.61</td>
<td>-7.60</td>
</tr>
<tr>
<td>After 1 year</td>
<td>4.21±1.31</td>
<td>-11.58</td>
</tr>
</tbody>
</table>

Postoperative and after 1 year (t= 4.546, with p-value 0.021*)

This table shows highly statistically significant decrease mean of postoperative and after 1 year compared to preoperative according to extension lag angle.
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(3) **Gross Motor Function Measurement (GMFM):**

The mean GMFM at the one year postoperative follow up was 69.1 (range 57.80 – 83.70) compared with mean preoperative GMFM of 53.3 (range 44.80 - 64.70) (Fig. 4).

![GMFM Chart](https://via.placeholder.com/150)

**Diag. 4:** Bar chart between preoperative and one year postoperative according to GMFM.

(4) **Gross Motor Function classification system:**

Preoperatively, 3 patients were GMFCS level II and 17 patients were GMFCS level III, however 15 patients were found to be GMFCS level II and 5 patients were found to be GMFCS level III at the one year postoperative follow up (Table 3).

<table>
<thead>
<tr>
<th>GMFCS</th>
<th>Pre-operative</th>
<th>One year Post-operative</th>
<th>Chi-square test</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>3 (15%)</td>
<td>15 (75%)</td>
<td>12.222 0.005*</td>
</tr>
<tr>
<td>III</td>
<td>17 (85%)</td>
<td>5 (25%)</td>
<td></td>
</tr>
</tbody>
</table>

\( x^2: \) Chi-square test; \( p-value <0.05 \) *

This table shows statistically significant difference between preoperative and postoperative according to GMFCS.

[B] **Radiological results by Koshino Index:**

The mean KI at the one year follow up was 1.14±0.12 (range 1.0 – 1.30) compared with mean preoperative KI of 1.54±0.29 (range 1.38 – 2.14) (Table 4).

<table>
<thead>
<tr>
<th>Period</th>
<th>Koshino index</th>
<th>Mean Diff.</th>
<th>Delta change</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-operative</td>
<td>1.54±0.29</td>
<td>-0.51</td>
<td>-0.33</td>
<td>7.435</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Post-operative</td>
<td>1.03±0.10</td>
<td>-0.40</td>
<td>-0.26</td>
<td>5.700</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>After 1 year</td>
<td>1.14±0.12</td>
<td>-0.40</td>
<td>-0.26</td>
<td>5.700</td>
<td>&lt;0.001**</td>
</tr>
</tbody>
</table>

Postoperative and after 1 years (t= 3.149, with p-value 0.003*)

\( p-value <0.001 \) HS**
This table shows highly statistically significant decrease mean of the one year postoperative compared to preoperative according to KI.

[D] Complications:
In this series, heel ulcer from the cast occurred 3 times, which resolved with frequent dressing and off-loading for 4 weeks. Recurrence of 5 degrees of flexion occurred in 3 patients (5 limbs). Anterior pelvic tilt was noticed in 3 patients (5 limbs) as well (Table 5).

Table (5): Complications distribution of the study group.

<table>
<thead>
<tr>
<th>Complications</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulcer from the cast</td>
<td>3</td>
<td>8.1%</td>
</tr>
<tr>
<td>Anterior pelvic Tilt</td>
<td>5</td>
<td>13.5%</td>
</tr>
<tr>
<td>Recurrence of 5 degrees of flexion</td>
<td>5</td>
<td>13.5%</td>
</tr>
<tr>
<td>No Complications</td>
<td>24</td>
<td>64.9%</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

This table shows that the Ulcer from the cast (8.1%), Anterior pelvic Tilt (13.5%), Recurrence (13.5%) and No Complications (64.9%) of complications.

There is a relation between anterior pelvic tilt and hamstring lengthening as it was noticed in patients done hamstring lengthening (Table 6).

Table (6): Relation between anterior pelvic tilt and hamstring lengthening.

<table>
<thead>
<tr>
<th>Anterior pelvic Tilt</th>
<th>Hamstring lengthening</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medial hamstring</td>
<td>No hamstring lengthening</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Yes</td>
<td>5</td>
<td>38.5%</td>
</tr>
<tr>
<td>No</td>
<td>8</td>
<td>61.5%</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Chi-square test: 7.636
*p-value: 0.006*

This table shows statistically significant relation between anterior pelvic tilt according to hamstring lengthening as it shows increase in anterior pelvic tilt incidence in cases where hamstring lengthening was done.

CASE PRESENTATION:

Preoperative data: Male 15 years old with GMFCS grade III, Spastic diplegic with history of hypoxic, encephalopathy and incubator, Flexion angle 40°, Extension lag 30°, Patella alta with KI 1.92, GMFM score was 47.6%.

Operative data: Patient had supracondylar extension osteotomy, PTA , Bilat. iliopsoas, adductor, med. Hamstring and lat. column lengthening with tibialis post advancement. Intraoperative compli-cation none. Bleeding about 50 cc. Implant used plate and screws.

Postoperative follow up: Above knee cast was applied for 6 weeks with knee in full extension. Patient was reviewed at 2 weeks postoperatively, then after 4 weeks for cast removal and then was reviewed monthly in 1st three months then at three months interval. Six weeks after surgery cast was removed and rehabilitation started. Fixed knee flexion angle become 7°and GMFM score become61.2%. Extension lag become 10° with KI 1.1
Fig. (8): Preoperative x-ray.

Fig. (9): 6 weeks postoperative.

Fig. (10): one year postoperative.
DISCUSSION:

In this study, we categorize the pathology of knee flexion into 2 main types; the myogenic type and the combined myogenic-arthrogenic type. A long standing isolated myogenic knee flexion deformity will eventually progress into a combined myogenic-arthrogenic fixed knee flexion deformity as the knee posterior capsule contracts and femoral condyles flattens due to the adaptive bony changes. Preoperative clinical assessment differentiates between the two types. As each type needs a different procedure for correction (Diag. 2).

In literature, various procedures were described for correcting FKFD in general without paying attention to differentiation between both types.

Temelli et al., Gage JR, Westberry et al., and Beals et al. (13-16) attempted hamstring lengthening and serial casting alone or combined with posterior knee capsulotomy; Isolated muscle lengthening procedure can correct the myogenic static type. However, with the combined type, it cannot even correct a FKFD as small as 5 to 10 degrees. In higher flexion degrees, acute correction after combined procedures (hamstring lengthening and posterior capsulotomy) for the combined type, increases the risk of neurovascular stretch injury therefore necessitating additional gradual correction by serial casting. The authors believe that in those cases, additional extensor mechanism tightening procedure has to be deferred to a later stage, when maximum extensor mechanism redundancy is reached with full knee extension in order to achieve a proper tension without compromising its repair.

Stout et al., Filho et al., Novacheck et al., and Rutz et al. (4,5,17-18) described SCFEO for correcting FKFD of 40° or less, as part of SEMLS.

Posterior cruciate ligament (PCL) is an integral part of the posterior knee capsule and it becomes pathologically contracted as part of posterior capsular contracture. Gavriliu et al. (19) believe that in long standing combined myogenic-arthrogenic FKFD it becomes increasingly difficult to stretch a contracted PCL unless it is incised along with the posterior knee capsule. PCL transection can compromise postero-lateral knee stability and may result in full extension with posterior tibial subluxation, which is something undesirable in a neurologically compromised child. (19) Additionally, in older children with long standing deformity, bony changes will resist correction by posterior capsulotomy alone. (22)

Young et al., and Klatt and Stevens (20,21) described guided growth as an alternative to posterior knee capsulotomy in the combined type. This procedure needs enough remaining time before physeal closure with unpredictable results in adolescents. Moreover, it cannot correct associated femoral rotational deformities and its gradual nature cannot permit proper simultaneous extensor mechanism retightening procedure.

Filho et al. (5) reported reduction in the mean FKFD angle from 15.91° to 5.68°. Their preoperative evaluation did not provide a clear clinical plan to differentiate between combined myogenic-arthrogenic and isolated myogenic knee flexion contracture elements. Their high recurrence rate of 22.7% and the excessive anterior pelvic tilting are explained by the fact that they didn’t attempt extensor mechanism retightening and attempting to lengthen hamstrings (if they weren’t already lengthened), respectively. Rutz et al. (18) didn’t mention the complication of excessive anterior pelvic tilting which we believe must have occurred.

In agreement with Healy et al. (22), we believe that in such scenario, hamstrings
will be the only protective structure against sciatic stretch and that lengthening them will lead to high chance of sciatic injury, especially in higher flexion degrees. In such clinical scenario, we recommend femoral shortening with extension. This will decrease sciatic tension but again this will cause a relative hamstring lengthening and might precipitate an excessive anterior pelvic tilting.

Filho et al. and Rutz et al.\(^{(5,18)}\) regarded SCFEO as a salvage procedure after failure of hamstring lengthening. It is worth mentioning that SCFEO cannot be regarded as a salvage operation. Rather, it has a specific indication in the combined myogenic-arthrogenic type which cannot be corrected by hamstring lengthening. Combining SCFEO with simultaneous or prior hamstring lengthening may cause excessive anterior pelvic tilting.\(^{(5,22)}\) In their study, Healy et al.\(^{(22)}\) found that both hamstring length and velocity increase substantially after extension without simultaneous hamstring lengthening.

Long standing walking in crouch pattern has been shown to cause progressive stretching of the Extensor mechanism with patella alta, oblong patella and tibial traction apophysitis. This will cause a clinically detectable extensor lag and will precipitate recurrence of crouch pattern.\(^{(4,7,17)}\) Accordingly, extensor mechanism re-tensioning should be regarded as a cardinal procedure to be done simultaneously with SCFEO.

Our study recommends combining SCFEO and PTA for correcting FKFD. It shows highly significant improvement in all the outcome measurements. It is a safe and effective operation that can correct up to 40 degrees of what we call the combined myogenic-arthrogenic FKFD.\(^{(4)}\) In addition, femoral rotational deformities could be corrected from the same osteotomy. Simultaneous extensor mechanism re-tensioning has been shown to improve knee extension power and reduce recurrence rate.\(^{(4,7)}\)

Novacheck et al.\(^{(17)}\) reported the first detailed technique of combined SCFEO and PTA in crouching patients. However, they lengthened hamstrings when deemed tight intra-operatively and all patients experienced anterior pelvic tilting.

In our study 38.5% of the cases that have done hamstring lengthening prior our operation experienced anterior pelvic tilting. On the other hand, none of the patients who didn’t have their hamstring lengthened developed anterior pelvic tilt.

We believe that differentiating between isolated myogenic and combined myogenic-arthrogenic knee flexion contracture is mandatory before intervention to decide between hamstring lengthening and SCFEO. When SCFEO is indicated, simultaneous hamstring lengthening should not be attempted to avoid excessive anterior pelvic tilting.

We routinely tensioned the extensor mechanism and the mean extension lag improved from 15.8 to 4.2 degrees at the latest follow up.

In our study, we experienced recurrence of 10 degrees of flexion in 3 cases despite PTA; and it is thought to be due to the ability of the growth plate to remodel in younger age.

Joseph et al.\(^{(23)}\), described combining femoral shortening only osteotomy and extensor mechanism re-tensioning. Extension at the osteotomy was not attempted except in 2 osteotomies. This is followed by a second stage of both lateral and medial hamstring lengthening with semitendinosus transfer, to avoid excessive anterior pelvic tilting.

We believe that shortening osteotomy alone without extension at the osteotomy level in FKFD cannot achieve full knee extension unless, theoretically, performed
Supra condylar femoral extension osteotomy with patellar tendon advancement to treat fixed knee.

distal to the femoral attachment of knee capsule. Moreover, even in cases of myogenic static knee flexion when hamstring lengthening is indicated, combining medial and lateral hamstring is not recommended in literature due to high incidence of resultant knee recurvatum in stance phase of gait (20).

In our study, we attempted femoral shortening with extension in few cases of higher flexion degrees (> 30), when we felt excessive posterior tension intra-operatively. We believe it resulted in excessive anterior pelvic tilt in some cases.

SCFEO has specific indications and should not be considered a final salvage procedure. This study is to document specific indication for the SCFEO and PTA. Clinically differentiating between isolated myogenic and combined myogenic-arthrogenic elements is important preoperatively and intra-operatively under anesthesia; in a FKFD, a combined myogenic-arthrogenic element is present and warrants an extension osteotomy without hamstring lengthening. Extensor mechanism re-tensioning is an essential part of the procedure that should be done to prevent recurrence and to improve the extension lag. This is to be done in the same operative session after achieving full limb extension to guarantee the maximum possible tension and secure reattachment of the extensor mechanism.

A considerable majority of studies on major orthopedic interventions in CP children are retrospective. (24-25) Generally, retrospective studies are known for their defective capability of controlling bias and confounding variables. (24-25) We believe that the prospective nature of our study adds strength to the results. Outcome measures for single event multilevel surgery in crouching CP children include a wide variety of objective and subjective assessment tools. (26)

A unique feature of this study is using the GMFM-88 score as outcome measure to detect changes in gross motor function in patients with CP undergoing combined SCFEO and PTA. All cases show significant improvement in their mean preoperative GMFM of 53.31 that became 69.09 postoperatively.

As regard the complications in this series, ulcer from the cast was noticed 3 times and was managed by frequent dressing and off-loading for 4 weeks. Recurrence of 5 degrees of flexion occurred in 5 limbs. There was no sciatic nerve stretch injuries in our study.

In this study concomitant hamstrings lengthening was not done in order to leave hamstrings intact in order to protect the sciatic nerve from stretch injury with the acute correction, and crouch gait improved without anterior pelvic tilting. Femoral shortening was done with higher flexion degrees when excessive posterior soft tissue tension was clinically detected intra-operatively, accepting the resultant excessive anterior pelvic tilting.

The strength of the study was that the same multi-disciplinary team assessed almost all of the patients over the whole study period, using GMFM-88 and observational gait analysis.

Another strength was that the patients were evaluated with different outcome measures. We have not found any previous studies with such broad outcome evaluation.

Our study had certain limitations. The number of children was small, and there was considerable variation in age at operation and in the functional levels of the patients. The type and number of previous operations and combinations of surgical procedures made it difficult to evaluate the effects of a specific procedure. Because we had no control group, and changes in gait function cannot be caused by surgery alone. In this study the quality of life assessment
instruments were not used. In addition, instrumented gait analysis was not used. We acknowledge such a study limitation.

Conclusion:

For crouching adolescents there are 4 questions must be answered:

**Frist**, differentiate between isolated myogenic flexion deformity and combined myogenic-arthrogenic knee flexion deformity by multidisciplinary preoperative assessments and examination under general anesthesia.

In combined myogenic-arthrogenic SCFEO is done. Extensor mechanism re-tensioning is an integral part of the procedure reduced to recurrence rate and to improve knee extension strength.

Hamstring lengthening should not be attempted in cases of combined myogenic-arthrogenic FKFD. Instead of that a femoral shortening osteotomy could be done, which results in a relative hamstring lengthening that might cause excessive anterior pelvic tilting, but on the expense of protecting the neurovascular structures from excessive tension.

**Second**, if there is no combined myogenic-arthrogenic flexion deformity we should assess isolated myogenic flexion deformity due to hamstrings by unilateral popliteal angle test.

**Third**, in cases of positive unilateral popliteal angle test, we should differentiate between apparent and true hamstring shortening by popliteal shift test; if the popliteal shift test is positive, that is apparent functional hamstring shortening and hamstring lengthening is not indicated.

**Forth**, if the unilateral popliteal angle is positive with negative popliteal shift test, true hamstring shortening is found. Hamstring contracture and hypertonia should be differentiated from each. Hamstring lengthening is done in cases of muscle contracture. On the other hand, BTX injection and tone management in cases of hypertonic spastic hamstrings.

**REFERENCES**


The surgical lengthening in the patients with cerebral palsy with quadriceps muscle pathology below the knee for the treatment of the clubfoot in the standing position by the cerebral palsy children with the replacement of the hip bone for the maximum lengthening and progression on the capable patients of the young postadolescents.

Mohamed Hamed, et al.,

The objective: To implement surgical lengthening in the patients with cerebral palsy with quadriceps muscle pathology below the knee for the treatment of the clubfoot in the standing position by the cerebral palsy children with the replacement of the hip bone for the maximum lengthening and progression on the capable patients of the young postadolescents.

In the cases and the methods: This was a prospective study conducted in the Rheumatology and Rehabilitation Department in Alpha Hospital in 2018 from September 2017 to 2018. The patients were selected from the patients who had clubfoot with cerebral palsy for the surgical lengthening in the standing position by the hip bone replacement for the maximum lengthening and progression on the capable patients of the young postadolescents.

The results: The results showed that the patients who had clubfoot with cerebral palsy for the surgical lengthening in the standing position by the hip bone replacement for the maximum lengthening and progression on the capable patients of the young postadolescents had improved results in terms of muscle strength and decreased pain.

Conclusion: This study showed that the surgical lengthening in the standing position by the hip bone replacement for the maximum lengthening and progression on the capable patients of the young postadolescents had improved results in terms of muscle strength and decreased pain.