Gait & Posture 64 (2018) 119–125

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Long-term outcomes over 10 years after femoral derotation osteotomy in ambulatory children with cerebral palsy

Ki Hyuk Sung[a,1], Soon-Sun Kwon[b,1], Chin Youb Chung[a], Kyoung Min Lee[a], Gyeong Hee Cho[a], Moon Seok Park[a,*]

[a] Department of Orthopaedic Surgery, Seoul National University Bundang Hospital, Gyeonggi, South Korea
[b] Department of Mathematics, College of Natural Sciences, Ajou University, Gyeonggi, South Korea

ARTICLE INFO

Keywords:
Femoral derotation osteotomy
Cerebral palsy
Anteversion
Gait analysis

ABSTRACT

Background: Femoral derotation osteotomy (FDO) is generally reported to be excellent for correcting the hip rotation and foot progression angles in children with cerebral palsy (CP). However, it is unclear how long the favorable outcomes are maintained.

Research question: This study was performed to evaluate the long-term outcomes at more than 10 years after FDO in children with CP.

Methods: FDO, as part of single event multilevel surgery to improve gait function, was performed at the intertrochanteric level with the patient in the prone position. The goal of the index surgery was femoral anteversion of 15°, measured using a modified trochanteric prominence angle test intraoperatively. All patients underwent three-dimensional gait analysis preoperatively and at 1 year and over 10 years postoperatively.

Results: Thirty-four ambulatory patients (53 hips) with CP undergoing FDO were included. The mean age at surgery was 7.8 years (SD = 3.0 years) and mean follow-up duration was 12.9 years (SD = 2.7 years). The mean hip rotation decreased significantly from 9.6° preoperatively to 3.1° at 1 year postoperatively ($p = 0.004$), and decreased significantly to -5.9° at the final follow-up ($p < 0.001$). The mean foot progression in stance decreased from 7.9° preoperatively to −7.4° at 1 year postoperatively ($p < 0.001$), and was maintained at -10.9° at the final follow-up. The GDI significantly improved from 68.2 preoperatively to 83.4 1 year postoperatively ($p < 0.001$), and was maintained at 82.3 at the final follow-up. No patients underwent revision surgery due to recurrence of rotation deformity.

Significance: Proximal FDO performed in the prone position provides favorable long-term outcomes at more than 10 years postoperatively, without recurrence of rotation deformity. To avoid under-correction or recurrence due to insufficient derotation, surgeons should consider not only dynamic gait analysis findings but also the measurement of anatomic femoral anteversion during intraoperative derotation.

1. Introduction

In-toeing gait due to increased femoral anteversion is the most commonly seen transverse plane deformity in children with cerebral palsy (CP) [1,2]. Gait problems associated with increased femoral anteversion include excessive internal hip rotation in all gait phases, leading to internal foot progression angle and poor foot clearance with excessive shoe wear, which causes increased tripping and falling, as well as a cosmetically poor gait pattern [3]. Increased femoral anteversion decreases the abduction moment arm of the hip abductors and this moment arm is restored with internal rotation; thus internal rotation may be a compensatory mechanism to preserve abduction capacity [4]. Femoral derotation osteotomy (FDO) is indicated to correct in-toeing gait and gait problems due to excessive femoral anteversion in patients with CP [5].

FDO is generally reported to be excellent for correcting the hip rotation and foot progression angles in children with CP [5–13]. However, it is unclear how long the favorable outcomes are maintained. Several studies evaluating the long-term outcomes of FDO showed recurrence rates between 0 and 39% [14–21]. The authors of these studies reported that the risk factors included the patient's age at surgery, greater plantar flexion, decreased hip abductor impulse and work,

* Corresponding author at: Department of Orthopaedic Surgery, Seoul National University Bundang Hospital, 82 Gumi-ro 173 Beon-gil, Bundang-Gu, Sungnam, Gyeonggi, 13620, South Korea.

E-mail address: pmsmed@gmail.com (M.S. Park).

[1] Ki Hyuk Sung and Soon-Sun Kwon contributed equally to the writing of this article.

https://doi.org/10.1016/j.gaitpost.2018.06.003
Received 4 December 2017; Received in revised form 23 May 2018; Accepted 3 June 2018
0966-6362/

decreased ankle joint impulse, greater hamstring and adductor spasticity, recurrence of flexed knee gait, and reduced preoperative walking speed.

In this study, we evaluated the long-term outcomes at more than 10 years after FDO in children with CP. We hypothesized that the improvements in CP in children undergoing would be maintained for more than 10 years postoperatively.

2. Materials and methods

This retrospective study was approved by the institutional review board of our hospital, which is a tertiary referral center for patients with CP. The need to acquire informed consent was waived due to the retrospective nature of the study.

The inclusion criteria were: (1) consecutive ambulatory patients with spastic CP; (2) patients who underwent single event multilevel surgery (SEMLS) including FDO between 1995 and 2006; and (3) patients who underwent three-dimensional (3D) gait analyses preoperatively and at 1 year and more than 10 years postoperatively. The exclusion criteria were: (1) patients with a history of gait-correcting surgery and (2) patients who had incomplete or missing 3D gait analysis data. The age at the time of surgery, sex, follow-up duration, Gross Motor Function Classification System (GMFCS) level, anatomical type (unilateral vs. bilateral involvement) of CP, and details of concomitant surgeries were obtained from the patients' medical records.

2.1. Operative protocol

FDO, as part of a SEMLS to improve the patient's gait pattern, was performed by a single pediatric surgeon (CYC) with 28 years of experience in pediatric orthopedics. The surgical procedures were performed after considering both the clinical and gait analysis findings. The indications for FDO were in-toeing gait with increased femoral anteversion and internal foot progression with increased hip internal rotation.

All patients underwent FDO at the intertrochanteric level, and the osteotomy site was internally fixated with a blade plate (Stryker, Selzach, Switzerland). FDO was performed with the patients in the prone position, and the goal of the index surgery was femoral anteversion of 15° [8]. The amount of derotation was determined not by the parameters of the gait analysis, but by an intraoperative physical examination, which was the modified trochanteric prominence angle test (TPAT). A guide pin was inserted parallel to the femoral neck axis on a frog-leg lateral hip radiograph. Intertrochanteric osteotomy was performed with an oscillating saw, and derotation was performed until the modified TPAT reached 15°. The modified TPAT is defined as the angle between a vertical line and the long axis of the leg when the guide pin was located horizontal to the ground (Fig. 1A–B).

All patients had a postoperative non-weight bearing period of 4–6 weeks, depending on the type of concomitant surgery. Subsequently, the patients were referred to a local rehabilitation center to perform muscle-strengthening exercises and receive gait training. Hardware removal was performed more than 1 year after the initial operation.

2.2. Acquisition of kinematic data and gait deviation index (GDI) score

A 3D gait analysis was performed 1 or 2 days before the surgery using a Vicon 370 system (Oxford Metrix, Oxford, UK) that was equipped with 7 cameras and 2 force plates. Markers were placed as for the Helen Hayes marker set, by a skillful operator with 21 years of experience for consistent anatomical landmark identification and marker positioning [22]. Patients walked barefoot on a 9-m walkway > 3 times, and 3 trials that represented a patient's typical gait pattern were selected. The data of the 3 trials were averaged to obtain the values of the index variables. The 3D gait analysis was repeated at 1 year and more than 10 years postoperatively. The gait deviation index (GDI) was calculated using pelvic and hip kinematic data in all three planes, knee and ankle data in the sagittal plane, and foot progression with control data as described by Schwartz [23]. A GDI score $\geq$100 denotes a non-pathological gait, and each 10-point decrement below 100 indicates 1 standard deviation from normal kinematics. Relevant kinematic values, including the mean pelvic rotation, mean hip rotation, foot progression in the stance phase, and GDI score, were the outcome measures.

2.3. Statistical analyses

The preoperative gait kinematics and GDI score were compared with values obtained at 1 year postoperatively and at the final follow-up, using repeated-measures analysis of variance with a Bonferroni post hoc test.

To consider bilateral cases, a linear mixed model (LMM) was applied for statistical analysis [24]. The annual postoperative changes in gait kinematics and GDI were adjusted for multiple factors using the LMM, with sex, age at the time of surgery, GMFCS level, anatomical type, DHL and TAL or Strayer procedure as the fixed effect model, and follow-up duration, laterality (left or right), and each subject as the random effect model. All statistical analyses were conducted using SAS 9.4.2 (SAS Institute, Cary, NC, USA) and R version 3.2.5 (R Foundation for Statistical Computing, Vienna, Austria); all statistics were two-tailed, and p-values < 0.05 were considered significant.

3. Results

Between 1995 and 2006, we performed FDO in 268 children. After applying the exclusion criteria, 234 patients were excluded and 34 children with 53 hips were finally included in the study. The majority of the patients had bilateral involvement (25 patients), based on an anatomical type; and GMFCS level II (20 patients), based on a functional classification. The mean follow-up duration was 12.9 ± 2.8 years

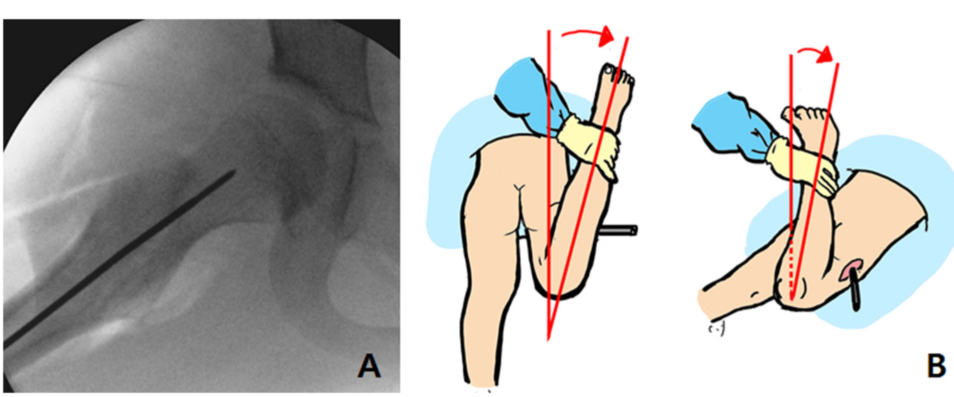

Fig. 1. (A) A guide pin is inserted parallel to the femoral neck axis on a frog-leg lateral hip radiograph, and intertrochanteric osteotomy and derotation are performed until the modified TPAT reaches 15°. (B) The modified TPAT is defined as the angle between a vertical line and the long axis of the leg when a guide pin is located horizontal to the ground.