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# Superior functional outcome after femoral derotation osteotomy according to gait analysis in cerebral palsy

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ABSTRACT

The femoral derotation osteotomy (FDO) is seen as the golden standard treatment in children with cerebral palsy and internal rotation gait. Variable outcomes with cases of over- and undercorrection mainly in the less involved patients have been reported. The determination of the amount of derotation is still inconsistent. 138 patients (age: 11 ($\pm$3.3) years) with cerebral palsy and internal rotation gait were examined pre- and 1 year postoperatively after distal or proximal FDO, using standardized clinical examination and 3D gait analysis. Three groups were defined retrospectively depending on the amount of derotation in relation to the mean hip rotation in stance (MHR) during gait analysis: Group A (derotation angle $>$ MHR $+$ 10°), Group B (derotation angle = MHR $\pm$ 10°), Group C (derotation angle $<$ MHR $-$ 10°), and compared according to their postoperative mean hip rotation. ANOVA with Bonferroni post hoc test was used for statistics ($p < 0.05$). Group B had the greatest benefit with the highest rate (86%) of good results (postoperative MHR = $\pm$15°). In contrast there were 14% cases of overcorrection and 5% cases of deterioration in Group A with only 81% good results and only 79% good results in Group C. It can be concluded, that it is less likely to have unsatisfactory outcomes if the amount of FDO is defined according to the findings of gait analysis compared with clinical examination.



## 1. Introduction

Internal rotation gait is one of the most common gait abnormalities in children with cerebral palsy [1]. The pathogenesis of internal rotation gait is still not fully understood and potentially includes both static and dynamic components. The increased femoral anteversion should be taken into consideration as a static component [2], although not all children with cerebral palsy and internal rotation gait show an increase of femoral anteversion [3,4]. Dynamic components might arise by muscular imbalance, increased muscle tone, spasticity and altered moment arms [5]. Precisely there exist increased moment arms of the internal rotator muscles combined with hip flexion deformity [6] and decreased moment arms of the abductors. The anterior parts of the glutei and the musculus tensor fasciae latae were considered as well as internal rotators [7].

Internal rotation gait relevantly influences gait since it may lead to lever-arm dysfunction [8,9], clearance problems (‘‘knocking knees’’), decrease of foot lever arm [6] and in consequence tripping. Increased pelvic rotation and excessive tibial torsion may be present concomitantly to compensate the hip malposition or due to lever-arm-dysfunction [8,10,11].

Despite the underlying cause is still not fully understood, addressing the static component by femoral derotation osteotomy (FDO) is seen as the golden standard treatment in patients with cerebral palsy [4,12–14]. The osteotomy can be performed either proximally as intertrochanteric osteotomy or distally as supracondylar osteotomy with comparable static and functional results [12,13,15,16].

Various studies reported the effectiveness of this procedure to correct internal rotation gait [4,13–15]. Nevertheless recent studies describe a variable outcome with cases of over- and undercorrection mainly in less involved patients [4,17] and recurrence [18,19].

One unsolved problem in the treatment of internal rotation gait is how to determine the amount of intraoperative derotation.

Previous studies showed that static examination methods such as measuring the femoral anteversion by CT scan [3,20] or

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measuring clinical passive range of motion do not well correlate with mean hip rotation observed in three-dimensional gait analysis [4,21]. Schwartz et al. [22] outlined that in patients where the amount of internal rotation in gait analysis matches the amount of anteversion angle, the outcome after FDO is superior compared to cases where anteversion angle is not reflected in dynamic parameters. Similar results were reported by Dreher et al. [4], who showed that outcome is good in cases where static (clinical examination) and dynamic (gait analysis) amount of internal rotation are comparably high.

However, in most of the past studies, intra-operative derotation amount primarily aimed to correct increased femoral anteversion. Hence a major question is if outcome becomes more predictable when the intra-operative amount of derotation is determined according to data from gait analysis.

Wren [23] recently showed clinically and statistically significant improvement of in-toeing after FDO when the gait analysis advice was followed, but poor outcome, when no gait analysis report was available or the recommendations were not implemented. Unfortunately the conclusion is limited as only 7 of 39 recommended FDOs were performed.

The purpose of this study was to evaluate if for patients in which derotation amount was close to mean hip rotation in stance during gait analysis FDO leads to a superior outcome compared to those, in which derotation amount differs from dynamic data.

## 2. Materials and methods

Standardized three-dimensional gait analysis and clinical examination were routinely performed for all ambulatory patients with cerebral palsy before and 1 year after surgery (14 months ± 5.0) at both participating institutions.

For the present cohort study, all ambulatory children with bilateral cerebral palsy (GMFCS levels I–III) and internal rotation gait that were treated with femoral derotation osteotomy under supervision of four surgeons (authors of the present paper) in the context of single-event multilevel surgery between 2000 and 2011 were selected retrospectively from the gait laboratory databases. 235 affected limbs from 138 children with a mean age of 11 (±3.3) years [range: 3.8–17.8] matched these criteria. In children with bilateral FDO one limb was selected randomly.

Femoral derotation osteotomy was performed either distally at the supracondylar level or proximally at the intertrochanteric level. In the past, the primary indication was, a clinically observed, disturbing internal rotation gait accompanied by an increased passive internal rotation in clinical examination and an increased femoral anteversion. The aim of FDO was mainly to correct increased femoral anteversion and to achieve a neutral clinical midpoint [24] between passive internal and external rotation. According to the findings of previous investigations [4] with cases of overcorrection, the indication for FDO changed over the time and the results of three-dimensional gait analysis became more important for the planning of derotation amount. The amount of derotation was measured intraoperatively by using K-wires placed proximally and distally to the osteotomy. The intraoperative amount of derotation averaged $25^\circ \pm 7^\circ$ (range: $5^\circ$–$40^\circ$). Inclusion criteria were the availability of gait data both pre- and 1 year postoperatively and a documentation of the amount of intra-operative derotation. Patients who underwent additional tibial (de-)rotational osteotomy were excluded from this study.

The evaluation included physical examination, videotaping and instrumented gait analysis according to a standardized protocol. For three-dimensional gait analysis a six camera Vicon system (Oxford Metrics, Oxford, UK) (Vicon 370 until 2002 in Heidelberg, since then Vicon 612; Vicon 460 in Basel) was used. Equivalency of both systems in Heidelberg was meticulously checked. Skin mounted markers were applied to bony landmarks of the patients according to the protocol of Kadaba et al. [25] and a knee alignment device was used to reduce mistakes in the transversal plane. The patients were asked to walk down a 7 m walkway barefoot at self-determined speed. The examinations were all performed by a physiotherapist and a study nurse specially trained in pediatric neuro-developmental therapy and with more than 8 years of experience with gait analysis.

Postoperative management consisted of early mobilization with weight-bearing transfers after the first 2–6 weeks and subsequent ambulation, depending on the patient's body weight and concomitant procedures. Thigh orthoses fixing both legs in about $10^\circ$ of external rotation were worn during the night for at least 6 months postoperatively to maintain correction.

The patients were retrospectively classified into three groups by the amount of derotation in relation to the mean hip rotation in stance during gait analysis. Group A was defined by a derotation amount of more than $10^\circ$ (twice the estimated measurement error [4]) larger than indicated by mean hip rotation in stance. Group B was defined by a derotation amount within $\pm 10^\circ$ of gait analysis advice. Group C was defined by a derotation amount more than $10^\circ$ less than mean hip rotation in stance.

Improvement of mean hip rotation in stance was calculated by subtracting postoperative from preoperative mean hip rotation in stance. Limbs with a postoperative mean hip rotation in stance phase in a range of $\pm 15^\circ$ were defined as good results.

Limbs with a postoperative mean hip rotation in stance phase more than $15^\circ$ external are considered to be overcorrected.

A postoperative mean hip rotation with an absolute value more than $10^\circ$ worse than preoperative is described as "worsening".

Moderate results present a postoperative mean hip rotation more than $15^\circ$ internal, without fitting the criteria for worsening.

### 2.1. Statistical methods

The outcome variables examined in this study were mean pelvic and mean hip rotation in the stance phase of gait, mean foot progression in the stance phase of gait and the improvement in mean hip rotation in stance.

Statistical analysis was performed using IMB SPSS Statistics 19. First the normal distribution of the outcome variables was confirmed by Shapiro Wilk test. All tests were two-tailed, and the significance level was set at $p < 0.05$. First, outcomes were compared between the pre- and postoperative gait analysis parameters for each of the three defined groups using Student's *t*-test. Then an analysis of variance (ANOVA) with Bonferroni post hoc tests was performed to compare the parameters between the defined groups.

The amount of derotation osteotomy and the preoperative anteversion measured by clinical examination were not normally distributed. For both variables non-parametric tests were used (Mann–Whitney *U*-test and Kruskal–Wallis test).

## 3. Results

57 limbs matched the criteria for Group A (excessive FDO), 67 limbs were allocated Group B (moderate FDO) and 14 limbs made up Group C (conservative FDO). Between these groups there were no significant differences concerning the age of the patients ($p = 0.347$), the functional level (GMFCS; $p = 0.399$; Table 1), the side of derotation ($p = 0.653$) and the proportion of distal to proximal femoral osteotomies ($p = 0.485$). Concomitant procedures are listed in Table 1.

Among the three defined groups, there is no significant difference in preoperative mid-point of passive hip rotation (hip extended [24]) and clinical anteversion ($p > 0.379$; Table 2).

In contrast the three defined groups show statistically significant ($p < 0.001$) differences in preoperative mean hip rotation in stance (Group A: $8^\circ \pm 10^\circ$, Group B: $22^\circ \pm 9^\circ$; Group C: $41^\circ \pm 8^\circ$).