Journal of Orthopaedic Surgery and Research

RESEARCH **Open Access**

Effects of femoral de-rotation on lower limb alignment using patient-specific guides with reliance on EOS scan, a retrospective study

Muhammad Taqi[1*], Jidapa Wongcharoenwatana[1], Munjed Al Muderis[1], Mustafa Alttahir[1], Kevin Tetsworth[2] and Claris Shi[1]

Abstract

The aim of this study is to evaluate the effects of midshaft femoral derotation surgery on the alignment of the lower limbs in the coronal and sagittal planes, as well as its impact on pelvic parameters in patients with significant femoral anteversion or retroversion.

A retrospective review was conducted on patients who underwent femoral derotation procedures using a minimally invasive patient-specific external guide system from January 2014 to January 2022 at Macquarie University Hospital. The surgery was done using preoperative 3D modeling and patient-specific external guides. Inclusion criteria comprised patients presenting with hip, knee, or patellofemoral symptoms due to high femoral anteversion who had complete EOS scans performed preoperatively and postoperatively. The EOS imaging system was utilized for accurate assessment and comparative analysis of alignment changes following the femoral derotation.

There were 22 limbs from 15 patients with an average age at operation of 30.41 ± 10.14 years (range 16.77–47.50). The average preoperative 3D EOS measurement of the femoral version in anteversion and retroversion groups were 32.84 ± 7.53° and −22.67 ± 13.32°, respectively. The postoperative femoral version in anteversion and retroversion groups were 13.39 ± 12.90° and 3.67 ± 9.29° having $p < 0.001$ and $p < 0.014$, respectively. Paired t-test was employed to calculate statistical values. Other parameters, including Hip-knee-shaft (HKS) angle, knee angle, pelvic tilt, pelvic incidence, mechanical lateral distal femoral angle (mLDFA), and coronal plane alignment of the knee, were not statistically significant differences.

This study provides evidence that femoral midshaft derotation surgery using patient-specific instrumentation (PSI) guides is an effective approach for correcting femoral anteversion and retroversion with no significant impact on coronal and sagittal lower limb alignment except femoral neck offset.

*Correspondence:
Muhammad Taqi
dr.taqi227@gmail.com
[1]Macquarie University Hospital, Sydney, Australia
[2]Royal Brisbane Hospital, Brisbane, Australia

Introduction

Rotational profiles of the lower limbs are mainly contributed by the femur and tibia, which have a significant impact on a person's gait pattern, overall mobility, joint biomechanics, and functional capabilities [1]. Femoral neck anteversion, also known as femoral torsion, is a crucial anatomical measurement that defines the angle between two lines in the axial plane perpendicular to the femoral shaft employing an EOS scan, CT, or MRI scan. The first line represents the axis passing through the proximal femoral neck region, while the second line represents the axis passing through the distal condylar region. This measurement provides essential information about the degree of twist/ torsion of the femur bone, which is crucial for understanding biomechanics and movement patterns of the hip joint [2]. The terms "anteversion" and "retroversion" refer to a femoral neck that tilts anteriorly or posteriorly relative to the condylar plane [3]. Femoral torsion is initially assessed through a clinical evaluation and is subsequently confirmed using radiological imaging [4, 5]. In patients with high femoral anteversion, the femoral neck causes anterior impingement on the acetabulum, resulting in pain. As a compensatory measure, patients adopt an "in-toeing" gait pattern to return the femoral neck angle to the physiological range, thereby alleviating discomfort and restoring hip abductor moment arms [6, 7]. This inward rotation may have consequential effects on lower limb biomechanics at the knee and ankle. Correspondingly, individuals with increased femoral external torsion experience pain relief through external rotation of the lower extremities [8].

Variation in femoral torsion significantly impacts the lever arms surrounding the hip joints [9]. Increased anteversion leads to a reduced hip extension and abductor moment arm and an increased hip flexion moment arm, consequently causing an abnormal gait pattern and pelvic instability [10–12]. Moreover, an increase in femoral anteversion denotes a rotational deformity in the axial plane, which is correlated with the emergence of anterior pelvic tilt and lumbar hyperlordosis. These conditions are found to precipitate early hip osteoarthritis and knee pain owing to biomechanical alterations [13, 14]. The relationship of abnormal femoral version with the development of hip OA is poorly defined. Studies have shown that high femoral anteversion leads to anterior impingement, causing increased joint stress and labral tears, initiating the cascade of osteoarthritis [15–17].

Correction of high femoral anteversion and retroversion entails femoral osteotomy and derotation. This correction restores the biomechanics of the hip and may influence the coronal and sagittal alignment of the lower limb. Paley has highlighted the potential for derotational femoral osteotomies to result in malalignment in the frontal plane due to variances between the mechanical and anatomical axes. Nonetheless, specific details regarding the extent of change at various levels were not specified. The role of this study is to measure the change in the coronal, sagittal alignment of the lower limb, including pelvis parameters, after correction of increased anteversion or retroversion. The parameters were measured utilizing an EOS scan, which is a biplane X-ray imaging system manufactured by EOS imaging (formerly Biospace Med, Paris, France).

There are several methods to assess femoral torsion, including imaging using radiography, computed tomography (CT), magnetic resonance imaging (MRI), EOS scan, and 3D modeling. The implementation of the EOS scan is based on the utilization of an ultrasensitive multiwire proportional chamber to minimize the X-ray dosage required for patient exposure. It enables 2D images to 3D reconstruction of spinal and lower limb osseous structures through stereoradiography [18, 19]. Various studies have validated EOS scans. Escott et al. found that when comparing the length of the femur, which was measured 10 times, the EOS scan was found to be more accurate than both the CT scanogram and conventional radiography ($p < 0.0001$) [20]. The interobserver agreement was excellent for anatomical bone length, mechanical axis, and angular measurements. Gheno et al., found no discernible variances between 3D EOS® and 3D CT-scan reconstructions in 3 different axial rotations [21].

The objective of this research is to assess the effects of midshaft femoral derotation surgery using patient-specific instrumentation (PSI) guides on the alignment of the lower limbs in the coronal and sagittal planes, as well as on pelvic parameters. The study will utilize validated EOS scan calculations to provide a comprehensive evaluation.

Methodology

After approval of IRB, a retrospective review of our database of patients who had femoral malrotation (anteversion or retroversion) and underwent femoral derotation procedures using a minimally invasive patient-specific external guide system was performed between January 2014 to January 2022 at Macquarie University Hospital. All data analyzed within the study will be sourced from the Primary treating surgeon. Patients presenting with hip, knee, or patellofemoral symptoms due to high femoral anteversion will be selected retrospectively.

Inclusion criteria were all patients who had midshaft femoral derotation surgery and had complete EOS performed preoperatively and postoperatively. Patients who have symptomatic high anteversion > 25 degrees or femoral retroversion were selected for femoral derotation. The surgery was done using preoperative 3D modeling and patient-specific guides. A postoperative EOS scan was recommended after 6 to 12 weeks to reduce the postoperative effects on limb posture. Patients were

Fig. 1 External Derotation guide for femoral derotation

excluded if they had undergone an operation without using a patient-specific instrumentation (PSI) or internal PSI guide or had incomplete radiographic or clinical records. The patients were excluded who had adjuvant femur lengthening or coronal realignment surgery (varising or valgising osteotomy), which would likely impact the attitude of the lower limb. Patients who had hip or knee replacement were also excluded due to inaccurate EOS measurements in the presence of the implant.

Femoral derotation surgery was performed on 39 patients. Out of these 15 patients with a total of 22 limbs were enrolled. Patient's demographic data, clinical presentations, preoperative and postoperative EOS scan values were collected.

3D patient-specific instrumentation jigs

A 3D image was created with the Materialise Mimics Medical Program using images from a high-resolution bilateral femur CT scan. The derotation is simulated on a 3D image, and the correction of femur rotation is re-evaluated by measuring the femoral anteversion angle. The reference value is the anteversion angle of the opposite limb or achievement of 10–15 degrees is the goal of derotation osteotomy. The level of osteotomy is measured from the tip of the greater trochanter as well as nail and screw size used for correction on 3-D modeling.

A patient-specific jig was fabricated using three-dimensional reconstruction techniques using Polyamide PA2200 in composition material. The jig has 2 proximal strands named 1 and 2, which are basically fixation guides for K-wires. Distally, there are two strands named 3B and 4B, which are at a special angle required for derotation to 3 A and 4 A. At the start, K-wires are passed through 1,2, 3 B, and 4 B, leaving 3 A and 4 A empty. (Fig. 1)

Surgical technique

The patient is placed in the supine position on a radiolucent table with a sandbag under the hip. Approximately 2–3 cm incision is made about 2 cm posterior to the greater trochanter's apex. The preferred starting position is the pyriformis fossa on both the anteroposterior and lateral images using a guide pin. The femoral canal is overreamed to 1–1.5 mm, which is more than the planned nail size, to allow minor rotation adjustments around the nail. The level of the osteotomy is determined by the pre-planning and PSI jigs. At the osteotomy site, cortices are drilled using a 4.5 mm drill to make an incomplete osteotomy via stab incision. The nail is inserted with gentle hammering. The parallel pins were placed over the trochanteric region and distal femur eccentrically. The PSI guide is fixed with K-wires to the eccentric cortex. The nail is then retracted back, and the osteotomy is completed using a fine small osteotome. The sizable nail is inserted just above the osteotomy site, and the distal femur is rotated either internally or externally by switching the distal K-wires in the jig (3B, 4B to 3 A and 4 A). The parallel wires of the jig depict the appropriate derotation of the femur. The intramedullary nail is locked with proximal and distal screws. After derotation, A paper goniometer is used to measure the angle of correction achieved using extreme pins. Therefore, the visual and jig system confirms the derotation.

Postoperatively, the patient was allowed to weight bear as tolerated with crutches. The skin sutures were removed two weeks after the surgery. Follow-up visits were done at intervals of 6 weeks, three months, six months, and one year.

Statistical analysis

Patient's demographic data and 3D measurements were analyzed with descriptive statistics and presented with Mean ± SD (range). Comparisons between pre and post-operative data were calculated and analyzed with a paired t-test. Statistical calculation was performed using Stata Statistical Software (College Station, TX: StataCorp LLC). Significance was set as $p < 0.05$. Both the Kolmogorov-Smirnov and Shapiro-Wilk tests confirmed that the data did not deviate from a normal distribution.

Results

A total of 39 patients underwent femoral derotation using customized external guides. However, several patients were excluded based on specific criteria: 10 did not have a preoperative EOS scan, 4 had previously undergone total knee replacements, and 1 had a total hip replacement. Additionally, 2 patients had high tibial osteotomies, 1 had a distal femur corrective osteotomy, and 1 was excluded due to simultaneous femur lengthening.

After exclusion, there were 22 limbs from 15 patients with an average age at operation of 30.41 ± 10.14 years (range 16.77–47.50). Total number of males were 9/15 (60%), and females 6/15 (40%). 12 cases were performed on the right limb, whereas 10 cases involved the left side. Most of the clinical presentation was patella mal-tracking or anterior knee pain 11 (50%) followed by patellar dislocation 4 (18.18%), hip pain 4 (18.18%), and in-toeing gait 3 (13.64%). The average preoperative 3D EOS measurement of the femoral version in anteversion and retroversion groups were 32.84 ± 7.53° and − 22.67 ± 13.32°, respectively.

The postoperative femoral version in anteversion and retroversion groups were 13.39 ± 12.90° and 3.67 ± 9.29°, respectively. Compared between pre- and postoperatively, the femoral version showed a statistically significant difference in both anteversion ($p < 0.001$, Cohen's d = 1.51, 95%CI = [14.13, 28.57]) and retroversion ($p = 0.014$, Cohen's d = 3.41, 95%CI = [5.17, 32.83])) groups. When combined patients from both groups, the femoral offset parameter showed a statistically significant difference ($p = 0.023$, Cohen's d = 0.54, 95%CI = [-3.78, -0.32]); however, there were no significant differences when evaluated separately: the anteversion group ($p = 0.062$) and the retroversion group ($p = 0.315$). Other parameters, including HKS angle, knee angle, pelvic tilt, pelvic incidence, mLDFA, and coronal plane alignment of the knee, were not statistically significant differences (Table 1).

Discussion

This study demonstrates femoral derotation surgery using external patient-specific instrumentation (PSI) guides, which entails a minimally invasive approach, less operative time, and provides accurate results compared to other techniques using surface marking or goniometer [22, 23]. Based on CT-based 3D printed and patient-specific guides, the degree of overcorrection and under-correction is nominal, making it a better choice to study the effect of derotation on pelvis, hip, and knee kinematics [24]. The studies have validated the interobserver validation of the EOS scan. EOS scan-based 3D modeling values were taken to examine the consequences of femoral derotation on lower limb alignment, which did not show any significant change in the anteversion and retroversion groups. This is a unique study as it underscores the impact on the anatomical bony alignment variation and physiological change in knee posture following femoral midshaft derotation.

The femoral derotation is carried out at three different levels such as proximal end, midshaft and distal femur. Proximal external derotational osteotomies lead to a change in the frontal plane [25]. External derotation proximal osteotomy leads to an increase in neck length, varus angulation, and the mechanical lateral distal femoral angle (mLDFA). Conversely, distal external derotational osteotomies result in an increase in valgus angulation due to a decrease in mLDFA. The observed effects can be attributed to differences in the mechanical and anatomical axes [26]. These changes in alignment were found to be more prominent in the Human cadaveric Femur [27, 28].

Furthermore, as Liu et al. found, osteotomies aimed at correcting varus and valgus misalignments in the proximal femur can potentially influence the femoral version [29].

As a clinical consequence, torsional osteotomies have an increased risk of unintentional implications on frontal plane alignment. This phenomenon is not commonly observed in mid-shaft diaphyseal osteotomies. It is noteworthy that in mid-shaft diaphyseal osteotomies, the disparate effects of proximal and distal osteotomies are presumably counteracted, resulting in a neutralizing effect. In this study, diaphyseal osteotomy was done, which was evaluated with preoperative and postoperative EOS scans, revealing consistent results without any significant change in the coronal(frontal) plane except femoral offset. This discrepancy might be attributed to the individualized approach provided by PSI guides, which potentially minimizes unintended coronal plane malalignment. The offset change underscores the lengthening of the femur neck because of the change in the coronal plane of the femur neck following derotation. The length of the femur neck is directly linked offset, which will be maximum at 0 degrees, therefore decreasing the high anteversion and retroversion will likely increase femoral offset. Restoration of offset through derotation is likely to improve the abductor lever arm and strength, leading to increased functional improvement [30].

Patients exhibiting increased femoral anteversion display not only an altered bone alignment but also modified joint kinematics during gait. These patients typically demonstrate a more internally rotated foot progression angle, increased hip internal rotation, increased hip flexion, and greater anterior pelvic tilt [31, 32]. Alexander et al. observed improved postoperative knee extension, which was decreased during the terminal stance phase pre-operatively [33]. Carty et al. compared patients with cerebral palsy before and after derotation, revealing a reduction of pelvic retraction after derotation [34]. In contrast, Kim et al. observed no change in pelvic rotation after derotation. Added to that, the change in foot progression angle is half the degree of derotation [35]. This study shows no change in pelvic tilt, incidence, and knee sagittal axis(flexion/extension) after derotation.

However, despite the benefits of preoperative 3D modeling, patient-specific instrumentation (PSI) guides, and EOS imaging, this study is subject to certain limitations. The retrospective nature of the study and the relatively small sample size may hinder the generalizability of the findings. The lack of functional gait assessment to assess compensatory changes in lower limbs was not evaluated. Furthermore, the absence of long-term follow-up restricts the ability to evaluate changes in lower limb alignment parameters over time. Future studies with larger cohorts, prospective designs, and extended follow-up periods are imperative to validate these findings and to investigate the enduring effects of femoral derotation on lower limb alignment.

Conclusion

This study provides evidence that femoral derotation surgery using patient-specific instrumentation (PSI) guides is an effective approach for correcting femoral anteversion and retroversion, with minimal impact on coronal and sagittal lower limb alignment. The axial derotation does not interfere significantly with pelvis position and knee posture. The utilization of advanced imaging like EOS scans enhances the ability to assess surgical outcomes improving patient care in the management of femoral malrotation. This study is shows comprehensive analysis of the anatomical bony alignment and the physiological alterations in knee posture resulting from femoral derotation. Anteversion and retroversion produced the same results, demonstrating no significant change in the sagittal and coronal plane after axial plane correction of femur derotation through midshaft osteotomy. This study will help to reinforce the site of osteotomy through midshaft as it causes no change in other planes compared to proximal and distal derotational osteotomies. This discovery paves the way for further examination using CT-based 3D modeling to deepen our comprehension of the subject.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-025-05774-4.

Supplementary Material 1

Acknowledgements

Nil.

Author contributions

1. MT Data collection, Manuscript writing2. JWAnalysis3. MAI Critical Review and surgical planning4. MADesigning 3D modelling5. KT Critical analysis6. CSProofreading.

Funding

No funding source was utilized.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethical approval

Ethical approval was approved by the Macquarie University Human Research Ethics Committee HREC Medical Sciences Committee, Sydney, Australia. (Reference No: MQCRG2024091) This research meets the requirements set out in the National Statement on Ethical Conduct in Human Research (2007, updated July 2018) (the National Statement). Patients have given informed consent for detailed information to be contained in this publication.

Consent to participate

Consent has been taken.

Consent for publication

Consent has been taken.

Competing interests

The authors declare no competing interests.

Received: 8 February 2025 / Accepted: 31 March 2025
Published online: 12 April 2025

References

1. Kainz HMGKA. Influence of femoral anteversion angle and neck-shaft angle on muscle forces and joint loading during walking. PLoS ONE. 2023;18(10):e0291458.
2. Scorcelletti MRNRJIA. Femoral anteversion: significance and measurement. J Anat. 2020;237(5):811–26.
3. Kate BR. Anteversion versus torsion of the femoral neck. Acta Anat (Basel). 1976;94:457–63. https://doi.org/10.1159/000144576).
4. Sangeux M, Mahy J, Graham HK. Do physical examination and CT-scan measures of femoral neck anteversion and tibial torsion relate to each other? Gait Posture. 2014;39(1):12–6. https://doi.org/10.1016/j.gaitpost.2013.05.020. Epub 2013 Jun 18. PMID: 23787150.
5. Jin S, Xu C, Cai H, Chen C, Lu Y, Wang Z, Shen M. Comparative analysis of physical examination, CT scan, and Three-Dimensional gait analysis in evaluating lower extremity torsion deformities in children with cerebral palsy. Med Sci Monit. 2023;29:e940948. https://doi.org/10.12659/MSM.940948. PMID: 37721931; PMCID: PMC10512746.

6. Lee MJ, Perez-Rossello JM, Weissman BN. Pediatric developmental and chronic traumatic conditions, the osteochondroses, and childhood osteoporosis. In: Resnick D, Kransdorf MJ, editors. *Imaging of Arthritis and Metabolic Bone Disease*. 1st ed. Philadelphia: Saunders/Elsevier; 2009. pp. 457–505. Available from: https://doi.org/10.1016/B978-0-323-04177-5.00025-2
7. Scorcelletti M, Reeves ND, Rittweger J, Ireland A. Femoral anteversion: significance and measurement. J Anat. 2020;237(5):811–26. https://doi.org/10.1111/joa.13249. Epub 2020 Jun 24. PMID: 32579722; PMCID: PMC7542196.
8. Lee MJ, Perez-Rossello JM, Weissman BN. Pediatric developmental and chronic traumatic conditions, the osteochondroses, and childhood osteoporosis. Imaging Arthritis Metabolic Bone Disease: Expert Consult - Online Print. 2009;457–505.
9. Kim HY, LSK, LNK. An anatomical measurement of medial femoral torsion. J Pediatr Orthop. 2012;21:552–7.
10. Scheys LVCASASPJI. Personalized MR-based musculoskeletal models compared to rescaled generic models in the presence of increased femoral anteversion: effect on hip moment arm lengths. Gait Posture. 2008;28(3):358–65.
11. Li HWYOJQXLTZYLFZZ. The role of femoral neck anteversion in the development of osteoarthritis in dysplastic hips. Bone Joint J. 2014;96–B(12):1586–93.
12. Femoral anteversion and, Root L. neck-shaft angles in hip instability in cerebral palsy. Laplaza FJ. J Pediatr Orthop. 1994;14(6):719–23.
13. Okuzu YGKOYKYKTMS. Hip-Spine syndrome: acetabular anteversion angle is associated with anterior pelvic Tilt and lumbar hyperlordosis in patients with acetabular dysplasia: A retrospective study. JB JS Open Access. 2019;4(1):e0025.
14. Tansey P. Hip and low back pain in the presence of femoral anteversion. A case report. Man Ther. 2015;20:206–11.
15. Parker EA, Meyer AM, Nasir M, Willey MC, Brown TS, Westermann RW. Abnormal femoral anteversion is associated with the development of hip osteoarthritis: A systematic review and Meta-Analysis. Arthrosc Sports Med Rehabil. 2021;3(6):e2047–58. https://doi.org/10.1016/j.asmr.2021.07.029).
16. Wedge JH, Munkacsi I, Loback D. Anteversion of the femur and idiopathic osteoarthrosis of the Hip:J bone joint Surg am, 71 (7) (1989), pp. 1040–3).
17. Labronici PJ, Castro GNPO, Neto SR, Gomes HC, Hoffmann R, Azevedo Neto JN, Franco JS, Rocha THN, Alves SD. Femoral anteversion and the neck-shaft angle: relationship with hip osteoarthritis. *Rev Bras Ortop (Engl Ed)* [Internet]. 2011;46(1):69–74. Available from: https://doi.org/10.1016/S2255-4971(15)30179-8.).
18. Melhem EAAERRGI. EOS(®) biplanar X-ray imaging: concept, developments, benefits, and limitations. J Child Orthop. 2016;10(1):1–14.
19. Chaibi YCTAB, et al. Fast 3D reconstruction of the lower limb using a parametric model and statistical inferences and clinical measurements calculation from biplanar X-rays. Comput Methods Biomech Biomed Eng. 2012;15:457–66.
20. Escott BGRBWAAJGCBPKSNUG. EOS low-dose radiography: a reliable and accurate upright assessment of lower-limb lengths. J Bone Joint Surg Am. 2013;95(23):1831–7.
21. Gheno RNEHBBMGLCABN. Three-dimensional measurements of the lower extremity in children and adolescents using a low-dose biplanar X-ray device. Eur Radiol. 2012;22(4):765–71.
22. Deng XLLLZLJ. Clinical application of femoral derotation osteotomy combined with medial patellofemoral ligament reconstruction for patellar dislocation with excessive femoral internal torsion. Asian J Surg. 2021;44(6):891–3.
23. Hartigan DEPIWJDBG. Femoral derotation osteotomy technique for excessive femoral anteversion. Arthrosc Tech. 2017;6(4):1405–10.
24. Baraza N CCZSMK. 3D - Printed patient specific instrumentation in corrective osteotomy of the femur and pelvis: A review of the literature. 3D Print Med. 2020;6(1):34.
25. Payne LZDPA. Intertrochanteric versus Supracondylar osteotomy for severe femoral anteversion. J Pediatr Orthop. 1994;14(1):39–44.
26. Paley D, PJP der kniegelenknahen. Deformitätenkorrektur [Principles of deformity correction around the knee. Orthopade. 2000;29(1):18–38.
27. Nelitz M, Wehner T, Steiner M, et al. The effects of femoral external derotational osteotomy on frontal plane alignment. Knee Surg Sports Traumatol Arthrosc. 2014;22:2740–6. https://doi.org/10.1007/s00167-013-2618-5.
28. Paley D. Rotation and angulation–rotation deformities. In: Paley D, editor. Principles of deformity correction. Berlin: Springer; 2001. pp. 235–6.
29. Liu RWTPHDDDCDR. The effect of varus and valgus osteotomies on femoral version. J Pediatr Orthop. 2009;29(7):666–75.
30. Alexander N, Cip J, Brunner RG, De Pieri E. Effect of femoral derotational osteotomy in patients with idiopathic increased femoral anteversion on joint loading and muscular demands. J Children's Orthop. 2024;18(5):510–22. https://doi.org/10.1177/18632521241269339).
31. Passmore EGHPMSM. Hip- and patellofemoral-joint loading during gait are increased in children with idiopathic torsional deformities. Gait Posture. 2018;63:228–35.
32. Alexander NSKLHPEKHWR. The impact of increased femoral antetorsion on gait deviations in healthy adolescents. J Biomech. 2019;86:167–74.
33. Alexander Nathalie BSLHPEKHSK. Effect of femoral derotation osteotomy on gait deviations in adolescent patients with idiopathic increased femoral antetorsion – preliminary results. Gait Posture. 2019.
34. Carty CPWHGJPTEJ, deLacy MBRN. The effect of femoral derotation osteotomy on transverse plane hip and pelvic kinematics in children with cerebral palsy: a systematic review and meta-analysis. Gait Posture. 2014;40(3):333–40.
35. Kim HY, Cha YH, Byun JY. Changes in gait parameters after femoral derotational osteotomy in cerebral palsy patients with medial femoral torsion. J Pediatr Orthop B. 2018;27(3):194–9.

Publisher's note