REV BRAS ORTOP. 2018;53(6):674–680

SOCIEDADE BRASILEIRA DE ORTOPEDIA E TRAUMATOLOGIA

RBO REVISTA BRASILEIRA DE ORTOPEDIA

www.rbo.org.br

Original article

The use of pediatric locked plates in the paralytic hip: preliminary results of 61 cases☆

Frederico Coutinho de Moura Vallim[a,b,*], *Henrique Abreu da Cruz*[a], *Ricardo Carneiro Rodrigues*[a], *Caroline Sandra Gomes de Abreu*[a], *Eduardo Duarte Pinto Godoy*[a], *Marcio Garcia Cunha*[a]

[a] *Serviço de Ortopedia Pediátrica, Hospital Estadual da Criança, Secretaria de Estado de Saúde (SES), Rio de Janeiro, RJ, Brazil*
[b] *Instituto Nacional de Traumatologia e Ortopedia (Into), Rio de Janeiro, RJ, Brazil*

ARTICLE INFO

Article history:
Received 30 June 2017
Accepted 11 September 2017
Available online 10 October 2018

Keywords:
Cerebral palsy
Hip dislocation
Osteotomy
Femur
Reconstructive surgical procedures

ABSTRACT

Objective: To evaluate the clinical and radiologic results of proximal femoral varus derotational and shortening osteotomy (OVRF) (Port., doesn't match name) with the use of a locked plate in patients with cerebral palsy, classified by the gross motor functional classification system as class IV or V.

Methods: A retrospective study of 42 patients (61 hips) with cerebral palsy, gross motor functional classification system class IV or V, submitted to OVRF. The minimal follow up was 24 months. This study evaluated clinical (age at surgery, gender, Gross Motor Functional Classification System class, anatomical cerebral palsy classification, and motor pattern), pre- and post-operative radiological (neck shaft angle, acetabular index, Reimers migration index and time until bone healing) characteristics, as well as post-operative complications.

Results: Mean pre-operative cervicodiaphyseal angle, acetabular index, and Reimers migration index were respectively 121.6°, 22.7°, and 65.4% in uncomplicated cases, and 154.7°, 20.4°, and 81.1% in complicated ones. All parameters were statistically significant difference between pre- and postoperative values ($p < 0.05$). The patients with postoperative complications had a greater cervicodiaphyseal angle and Reimers migration index ($p < 0.0001$). There were no differences in clinical characteristics, time of immobilization, or bone healing. Fourteen patients had postoperative complications (33.3%), but only six required surgical treatment.

Conclusion: The locked plate is a safe resource, with low complication rates and reproducible technique for OVRF in the cerebral palsy population classified as gross motor functional classification system IV and V. Greater cervicodiaphyseal angles and Reimers migration index are associated with greater chances of postoperative complications, as well as gross motor functional classification system V classification.

☆ Study conducted at Serviço de Ortopedia Pediátrica, Hospital Estadual da Criança, Secretaria de Estado de Saúde (SES), Rio de Janeiro, RJ, Brazil.

* *Corresponding author.*
E-mail: fredericovallim@gmail.com (F.C. Vallim).

https://doi.org/10.1016/j.rboe.2017.09.009
2255-4971/

O uso de placas bloqueadas pediátricas no quadril paralítico: resultados preliminares de 61 casos

RESUMO

Objetivo: Avaliar os resultados clínicos e radiológicos da osteotomia varizante, de rotação e encurtamento da extremidade proximal do fêmur (OVRF) com uso de placa bloqueada em pacientes com paralisia cerebral classificados pela escala *Gross Motor Functional Classification System* como IV e V.

Métodos: Estudo retrospectivo de 42 pacientes (61 quadris) com paralisia cerebral, *Gross Motor Functional Classification System* IV e V, submetidos a OVRF. O seguimento mínimo pós-operatório foi de 24 meses. Foram avaliadas as características clínicas (idade na data da cirurgia, sexo, *Gross Motor Functional Classification System*, classificação geográfica da paralisia cerebral, padrão de acometimento motor), radiológicas pré e pós-operatórias (ângulo cérvico-diafisário [ACD], índice acetabular [IA], índice de Reimers [MP] e tempo até a consolidação radiológica) e complicações pós-operatórias.

Resultados: O ângulo cérvico-diafisário, índice acetabular e o índice de Reimers médios pré-operatórios foram respectivamente de 121,6 °, 22,7 ° e 65,4% nos casos não complicados, *vs*. 154,7 °, 20,4 ° e 81,1% nos que evoluíram com complicações pós-operatórias. Todos os parâmetros apresentaram diferença significativa entre os valores pré e pós-operatórios (p < 0,05). O ângulo cérvico-diafisário e o índice de Reimers foram maiores no grupo com complicações (p < 0,0001). Não houve diferenças nas características clínicas, no tempo de imobilização ou consolidação, exceto em relação ao grau *Gross Motor Functional Classification System* V (p < 0,0001). Foram observadas complicações pós-operatórias em 14 pacientes (33,3%). Desses, somente seis necessitaram reintervenção cirúrgica.

Conclusão: A placa bloqueada é um recurso seguro, com baixa taxa de complicações cirúrgicas e de técnica reprodutível para a OVRF na paralisia cerebral *Gross Motor Functional Classification System* IV e V. Maiores ângulos cérvico-diafisário, índices de Reimers e graus de *Gross Motor Functional Classification System* V estão ligados a maiores chances de complicações pós-operatórias.

Palavras-chave:
Paralisia cerebral
Luxação do quadril
Osteotomia
Fêmur
Procedimentos cirúrgicos reconstrutivos

Introduction

Cerebral palsy (CP) is the most common cause of physical disability in children in developed countries,[1] affecting 2.0–2.5 of every 1000 live births.[2] One of its most morbid orthopedic complications is hip dislocation, whose incidence is directly proportional to disease severity, according to the Gross Motor Function Classification System (GMFCS) functional scale. This scale defines five groups of patients according to the overall motor impairment and their functional performance.[3] Types IV and V present the highest incidence of hip pathologies, with dislocation rates that reach up to 70% and 90%, respectively. Meanwhile, types I, II and III have a lower incidence of this problem, with respective rates of up to 5%, 17% and 50%.[1,4–7] Another factor related to the risk of paralytic hip dislocation is the inability to walk after the age of 5 years.[1,7,8] Paralytic dislocation of the hip is often associated with pain and deterioration in gait, seating, and perineal hygiene care, and consequent worsening of quality of life.[1,3,6,7,9,10]

Patients classified as GMFCS IV and V present, in addition to the orthopedic problems, clinical alterations that also affect disease prognoses, such as seizures, malnutrition, sarcopenia, osteopenia, and low cognitive capacity.[2,11,12] Of these, osteopenia may have a direct influence on the surgical procedure that is performed in most patients: varus derotational and shortening osteotomy (VDSO) of the proximal portion of the femur.[13,14] These surgeries are classically made with the use of angled plates; however, aiming to improve bone fixation under osteopenia conditions, modern implants with locking screws technology have been developed.[15–17]

The recent arrival of these implants in Brazil allowed their use in the treatment of hip deformities in the large population of neuropathic children, as well as in children with non-neurological diseases. This material became available at this service in 2013 and since then around 140 patients have undergone osteotomies of the upper third of the femur. Of these, approximately 100 surgeries were performed in cases of paralytic dislocation in patients with spastic CP classified as GMFCS IV and V. Given the absence of a Brazilian case series with the use of these implants, this study is aimed at demonstrating the preliminary results of the authors' initial experience with them.

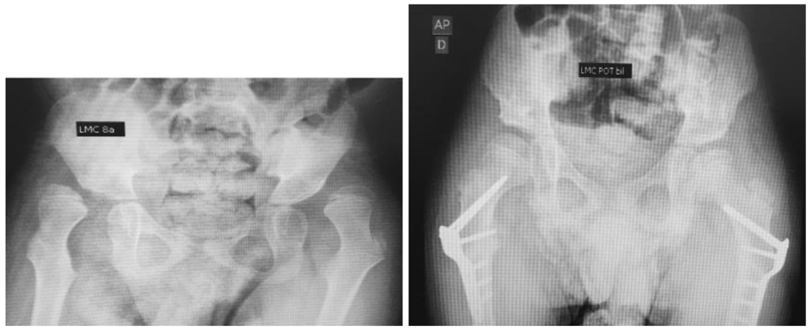

Fig. 1 – Anteroposterior radiographic images in the preoperative period (left) and at 2 years postoperative (right) of a patient undergoing bilateral hip reconstruction (VDSO + open reduction + bilateral Dega type supra-acetabular osteotomy).

Methods

After the project was approved by the local Research Ethics Committee, the authors retrospectively assessed the medical record data of patients with spastic CP, classified as GMFCS IV and V, operated at this hospital from June 2013 to June 2015, submitted to VDSO. The osteotomy was performed alone or associated with other procedures as part of the multilevel approach recommended for the orthopedic surgical treatment in CP, called single-event multilevel surgery (SEMLS).[18,19] The following data were compiled and tabulated in Excel: age, gender, anatomic classification of CP (diparesis, tetraparesis, hemiparesis), pattern of motor involvement (pyramidal/spastic or extrapyramidal/non-spastic), type of implant used, functional classification (GMFCS), concomitant surgeries, and peri and postoperative complications. The radiographic criteria evaluated included the cervicodiaphyseal angle (CDA), acetabular index (AI), Reimers migration index (RMI), and time to radiographic bone consolidation.

Patients who could not be followed-up for a minimum period of 2 years postoperatively were excluded from the study, as well as those with extrapyramidal motor involvement, those classified as GMFCS I, II or III, and those who did not present complete data in medical records.

Radiographs were evaluated by three authors of the study, two fourth-year residents in pediatric orthopedics, and one senior pediatric orthopedist at this institution (Fig. 1). CDA, AI, and RMI were measured as broadly described in the literature, in a panoramic anteroposterior hip radiograph. The internal rotation of the lower limbs on this radiograph was enough to compensate the anteversion of the femoral neck, usually close to 40 degrees,[20] as estimated previously by the trochanteric prominence test in the prone physical examination.[21,22] The authors used the Kalen and Bleck classification to assess the progression of the degree of migration, in which a change of less than 10% was considered unaltered, an increase of more than 10% was considered as a worsening of the condition, and a reduction of more than 10%, an improvement.[23]

Radiographic exams were performed preoperatively, as well as in the immediate postoperative period (IPO), one month, six months, and one year postoperatively, in the panoramic anteroposterior and double abduction views of the hip. The osteotomy was considered to be consolidated when a bone callus that crossed the fracture focus in at least three of four cortices was observed in the two radiographic projections.

The surgical technique used for VDSO was that previously described by Rutz et al.,[15] except for the fact that, in the present study, a 1.5-cm femoral shortening was made; the distal fragment was secured with various configurations of cortical and locking screws, which will be the focus of discussion in subsequent studies, and will not be detailed here.

Postoperative bilateral long leg hip spica cast immobilization was used in patients who also underwent open hip reduction or acetabuloplasty. In cases in which the VDSO was isolated, a double abduction boot cast immobilization was used, consisting of a bilateral plaster cast with an abductor bar. The plaster cast was used for two weeks, at which point patients underwent their first postoperative outpatient assessment. If the patient was comfortable and had no skin lesions related to the cast, a follow-up appointment was rescheduled for every other week; the plaster was removed at the surgeon's discretion, according to the radiographic image of the initial bone callus. In the case of long leg hip spica cast, the patient was taken to the operation room after four weeks of surgery and the immobilization was replaced by a double abduction cast, whose removal followed the described previously protocol.

Postoperative complications were classified by the main author according to the adapted Clavien–Dindo method,[24] in which grade I complications are those that do not require a change in standard treatment, grade II require a change in outpatient treatment, grade III require radiological or surgical intervention, grade IV are associated with long-term morbidity or life-threatening, and grade V result in patient death.[25]

The normality of the quantitative data was assessed with the Kolmogorov–Smirnov test. The AI, CDA, and RMI values were compared using the Student's t-test for paired samples. Unpaired samples were compared with Student's t-test for unpaired samples. Qualitative data were compared using Fisher's exact test. The online Quickcalcs version of the Graphpad software was used for these evaluations (Graphpad Software, San Diego, CA, USA). A significance level of 5% ($\alpha = 0.05$) was adopted.

Table 1 – Sample characterization.

GMFCS	Number of patients (hips)	Gender (male:female)	Mean age (years)
IV	8 (15)	6:2	7.6
V	34 (46)	11:23	9.8
Total	42 (61)	17:25	8.7

GMFCS, Gross Motor Function Classification System.

Results

Eighty patients with CP classified as GMFCS IV or V underwent surgery from June 2013 to June 2015. Of these, 42 patients (61 hips) were included in the study group; the others were excluded due to the absence of standardized radiographs that allowed adequate measures (18 cases) and the remainder because they did not complete the two years of outpatient follow-up (20 cases). The majority of patients were female (25 patients, 40 hips). The mean age was 8.7 years (range: 4–14 years). All patients had spastic tetraparesis; 34 (46 hips) were classified as GMFCS V and eight (15 hips) as GMFCS IV (Table 1). An isolated VDSO was performed in 30 hips, while it was associated with Dega-type supra-acetabular osteotomy in 31 hips. In these latter 31 hips, an arthrotomy was performed for open reduction of the joint in 17 cases (54.8%). Multiple tenotomies were performed in all patients; tenotomy of the intrapelvic psoas was performed in 17 hips (27.8%), psoas tenotomy at the small trochanter in 44 (72.1%), long adductor tenotomy in 51 hips (83.6%), gracilis tenotomy at its origin in 13 hips (21.3%), and distal lengthening of the medial hamstrings in 47 limbs (77%). In two patients, the flexor-pronator musculature was lengthened. The implant used was the 110° 3.5-mm pediatric proximal femur LCP (Synthes, Oberdorfen, Switzerland) in 56 cases (90.3%), the 100° plate in five cases (8.06%) and the 120° plate in one case (1.6%). The mean follow-up time was 41.36 months (from 26 to 59), while the mean postoperative immobilization time was 5.5 weeks (from 3 to 12) and the mean time until consolidation was 12.75 weeks (from 6 to 52).

The mean preoperative CDA was 154.6° and the mean postoperative was 119.6°, with an average reduction of 35.1°. Regarding the AI, the mean reduction was 6.03°, with pre and postoperative means of 21.09° and 15.06°, respectively. Finally, the RMI presented a mean reduction of 66.5% between the pre and the immediate postoperative period (IPO), while the reduction in the late postoperative period (LPO) was 58.92%, i.e., there was a loss of 7.58% in the late postoperative follow-up, in relation to the preoperative period. A significant difference was observed between pre and postoperative CDA and AI ($p < 0.0001$), as well as between pre and postoperative RMI ($p < 0.0001$; Table 2). The worsened RMI observed in the LPO in relation to the IPO was considered unaltered according to the classification of Kalen and Bleck. Meanwhile, in all cases, an improvement in migration was observed after surgery, according to the same classification.[23] The monthly rate of postoperative progression of the RMI, which was on average 0.31%/month, was calculated by dividing the difference between the RMI at the LPO and that observed at the IPO by the time of follow-up.

Postoperative complications were observed in 14 patients (33.3% of the patients, or 29.5% of the hips), a second surgical procedure was necessary for six patients (14.3%). All complications were observed in GMFCS V patients. Of these complications, six were classified as type II of Clavien-Dindo, in which only therapeutic treatment was necessary for an outpatient setting, with six pressure ulcers (five in the sacral region and one in the calcaneus). Six patients had complications classified as type III that required a supplementary orthopedic approach; five cases of re-dislocation and one case of pseudoarthrosis. Two patients presented clinical complications and required treatment under hospital admission; they were classified as type IV (one case of intestinal obstruction due to adhesions and one case of pneumonia requiring parenteral antibiotic therapy).

A higher mean CDA was observed in the group with complications (154.7°) when compared with the uncomplicated group (121.6°), a statistically significant difference ($p < 0.0001$). The difference between the mean AI of complicated (20.48°) and uncomplicated (22.71°) cases was not statistically significant ($p = 0.201$). Finally, mean RMI was statistically lower in uncomplicated cases (65.44%) than in complicated cases (81.17%; $p = 0.0054$). This indicates an association between greater CDA and greater RMI with a higher rate of complications, whereas the same was not observed with AI (Fig. 2).

Table 2 – Summary of radiographic indices and complications.

	CDA pre (degrees)[a,b]	CDA post (degrees)[b]	AI pre (degrees)[b]	AI post (degrees)[b]	RMI pre (%)[a,b]	RMI post (%)[b]	Immobilization time (weeks)	Consolidation time (weeks)
Complicated cases	154.7	120.5	20.4	16.4	81.1	19.9	5.8	13.8
Non-complicated cases	121.6	118.7	22.7	13.7	65.4	2.1	5.2	11.7
Total	154.6	119.6	21.09	15.06	69.9	11.01	5.5	12.75

CDA, cervicodiaphyseal angle; AI, acetabular index; RMI, Reimers' migration index. Percentage of lateral migration of the femoral head.

[a] Statistically significant difference between groups with and without complication ($p < 0.0001$).

[b] Statistically significant difference between pre and postoperative values ($p < 0.05$).

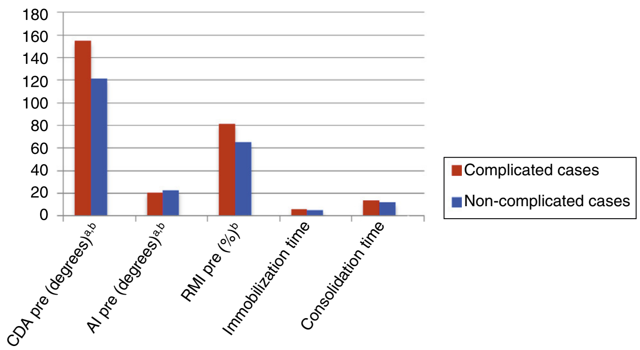

Fig. 2 – Association of radiological factors with the incidence of postoperative complications. CDA, cervicodiaphyseal angle; AI, acetabular index; RMI, Reimers' migration index. Percentage of lateral migration of the femoral head. [a]Statistically significant difference between groups with and without complication ($p < 0.0001$). [b]Statistically significant difference between pre and postoperative values ($p < 0.05$).

No statistical significance was observed when assessing the relationship between complications, side, and age. However, in the GMFCS functional classification, a significant association was observed with class V in relation to IV ($p < 0.0001$). No statistically significant association was observed regarding the complications and the surgeries associated to the VDSO.

Discussion

The prevalence of paralytic hip dislocation in patients with spastic CP is directly proportional to the degree of functional impairment (GMFCS), reaching up to 70% and 90% in grades IV and V, respectively.[1,4–7] Failure to identify this dislocation early in the follow-up of patients with spastic CP may lead to significant pain and severe limitation of patients' quality of life.[1,26,27] This fact led to the creation of early prevention and diagnosis programs through an intermittent programmed follow-up of GMFCS IV and V patients in several orthopedic centers worldwide, which allowed a preventive surgical approach and a consequent lower rate of dislocations with secondary joint degeneration.[4,7] In the state of Rio de Janeiro, Brazil, the logistics for the implementation of a similar public health program are hampered by the low number of patients undergoing adequate physical therapy, as well as the high cost of botulinum toxin, commonly used to delay the age at which patients undergo surgical procedures. The difficulty of using this toxin in the iliopsoas musculature, fundamental in the deformity in question, is also a limiting factor. Together, these factors are linked to the dislocation and subluxation; however, the literature does not present definitive evidence.[26]

Cooke et al.[28] retrospectively studied 462 patients to identify factors associated with the paralytic hip dislocation in CP patients, and determined an association of this with a higher AI; these authors indicated that AI > 30° before 4 years of age is an important predictor. In the present sample, no relationship was observed between AI and the incidence of complications in the treatment of hip dislocation. However, the present authors were unable to perform an assessment similar to that of Cooke et al., as the entire sample in the present study consisted of patients who already presented dislocation or subluxation, which would cause a selection bias if a parallel were to be drawn. In addition, the definition of AI as a predictor can be questioned, as it is known that the femoral head positioned in the hip helps to shape the acetabulum, which is well documented in hip development in cases of dysplasia[29,30]; the AI alteration could, therefore, be seen as a consequence, not a cause of the dislocation.

In 2006, a Norwegian group[10] evaluated the natural history of non-operated hips in 76 patients with CP and found a relationship between paralytic dislocation and two factors: no independent ambulation for up to five years of age and degree of motor involvement, with a higher RMI progression in tetraparesis in relation to diparesis. These data were confirmed in a subsequent study by the same group in 2012.[7] A progression of RMI at one year of 7.58% was observed in the present study, with a rate of 0.31%/month, which is lower than that described in the literature, which is around 12% a year in untreated cases.[7,10] Therefore, this intervention slows down but does not completely prevent RMI progression. There is no evidence that postoperative non-surgical measures, such as physical therapy, can alter this parameter. Thus, the challenge is to define the best time to perform the VDSO in order to require as few subsequent surgical interventions as possible. At the same time, this challenge becomes greater when trying to determine the moment at which the femoral head is positioned in the hip and leads to acetabulum remodeling, which may not necessarily be at the same moment that it decreases the chance of the patient requiring new hip surgeries.

Other authors correlated RMI with the chance of re-dislocation, which was consistent with the present results.[31] This association could be attributed to local adaptive factors, such as greater soft-tissue retraction in cases where there is greater lateral hip migration. It can also be hypothesized that this finding is related to the severity of the patient's functional impairment and spasticity, as patients with GMFCS IV and V tend to have higher RMI and a greater incidence of hip dislocation.[4,12,31]

The consolidation time was comparable to that described in the literature, as well as the preoperative CDA and RMI measurements and their postoperative improvement,[15–17] even with the use of several implants (locking blade plate or non-locking blade plate in these studies). The rate of complications in the literature after reconstructive surgeries of the paralytic hip was in the range of 26%, vs. 29.5% in the present sample. However, the present rate of orthopedic complications was 6/61, or 9.83%, which was lower than reported in a New Zealand study,[17] but somewhat higher than another study conducted in Switzerland (5.7%).[15] A more recent Australian study assessed the results of the use of a locking blade plate in a group with a short follow-up and did not observe cases of failure in the surgical treatment in the period until consolidation. Since all the complications in the present study that required a new surgical approach occurred prior to osteotomy consolidation, the authors infer that this technique requires a learning curve still in progress in the present service to reach lower complication rates equivalent to that of reference services, which perform over 150 osteotomies per year.[16]

The present study had limitations, such as the absence of a control group, composed of GMFCS IV and V patients who underwent reconstructive surgeries of the hip with non-locking plates. This control group is currently under follow-up, and this comparative study is the current focus at the present institution. Nonetheless, the number of operated patients is a considerable and unprecedented sample in the Brazilian literature. The inclusion of intraoperative measures of bleeding, as well as the assessment of hospital cost for both techniques, and hospitalization and complications, it is important to evaluate the feasibility of using these locking implants in the public healthcare system. These data are under evaluation and the authors intend to publish a specific study on the issue.

Conclusion

In the present sample, paralytic hip reconstruction surgery performed with a 3.5-mm pediatric LCP hip plate was shown to be a safe, reproducible technique with a low rate of surgical complications, that reduces the speed of hip lateral migration in non-ambulatory CP patients. Higher preoperative CDA and RMI were associated with higher rates of postoperative complications, as well as GMFCS V classification.

Conflicts of interest

The authors declare to have no conflicts of interest.

REFERENCES

1. Soo B, Howard J, Boyd R, Reid S, Lanigan A, Wolfe R, et al. Hip displacement in cerebral palsy. J Bone Joint Surg Am. 2006;88(1):121–9.
2. Reddihough DS, Collins KJ. The epidemiology and causes of cerebral palsy. Aust J Physiother. 2003;49(1):7–12.
3. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol. 1997;39(2):214–23.
4. Connelly A, Flett P, Graham HK, Oates J. Hip surveillance in Tasmanian children with cerebral palsy. J Paediatr Child Health. 2009;45(7–8):437–43.
5. Hagglund G, Alriksson-Schmidt A, Rodby-Bousquet E, Wagner P, Westbom L. Prevention of dislocation of the hip in children with cerebral palsy: 20 year results of a population based prevention programme. Bone Joint J. 2014;96(11):1546–52.
6. Hägglund G, Lauge-Pedersen H, Wagner P. Characteristics of children with hip displacement in cerebral palsy. BMC Musculoskelet Disord. 2007;8:101.
7. Terjesen T. The natural history of hip development in cerebral palsy. Dev Med Child Neurol. 2012;54(10):951–7.
8. Howard CB, McKibbin B, Williams LA, Mackie I. Factors affecting the incidence of hip dislocation in cerebral palsy. J Bone Joint Surg Br. 1985;67(4):530–2.
9. Graham HK, Harvey A, Rodda J, Nattrass GR, Pirpiris M. The Functional Mobility Scale (FMS). J Pediatr Orthop. 2004;24(5):514–20.
10. Terjesen T. Development of the hip joints in unoperated children with cerebral palsy: a radiographic study of 76 patients. Acta Orthop. 2006;77(1):125–31.
11. Schlitt HJ. Painful hip dislocation in cerebral palsy. Lancet. 2002;359(9310):907–8.
12. Kerr Graham H, Selber P. Musculoskeletal aspects of cerebral palsy. J Bone Joint Surg Br. 2003;85(2):157–66.
13. Rhodes J, Blanchard A. Osteopenia of the hip joint in cerebral palsy – does this affect hip stability? Dev Med Child Neurol. 2016;58(11):1103–4.
14. Moon SY, Kwon SS, Cho BC, Chung CY, Lee KM, Sung KH, et al. Osteopenic features of the hip joint in patients with cerebral palsy: a hospital-based study. Dev Med Child Neurol. 2016;58(11):1153–8.
15. Rutz E, Brunner R. The pediatric LCP hip plate for fixation of proximal femoral osteotomy in cerebral palsy and severe osteoporosis. J Pediatr Orthop. 2010;30(7):726–31.
16. Zhou L, Camp M, Gahukamble A, Khot A, Graham HK. Cannulated, locking blade plates for proximal femoral osteotomy in children and adolescents. J Child Orthop. 2015;9(2):121–7.
17. Zhang S, Wilson NC, Mackey AH, Stott NS. Radiological outcome of reconstructive hip surgery in children with Gross Motor Function Classification System IV and V cerebral palsy. J Pediatr Orthop B. 2014;23(5):430–4.
18. Neve A, Evans G, Patrick J. Simultaneous multiple operations for spastic diplegia. J Bone Joint Surg Br. 1993;75(3): 488–94.
19. Thomason P, Baker R, Dodd K, Taylor N, Selber P, Wolfe R, et al. Single-event multilevel surgery in children with spastic diplegia: a pilot randomized controlled trial. J Bone Joint Surg Am. 2011;93(5):451–60.
20. Robin J, Graham HK, Selber P, Dobson F, Smith K, Baker R. Proximal femoral geometry in cerebral palsy: a population-based cross-sectional study. J Bone Joint Surg Br. 2008;90(10):1372–9.
21. Davids JR, Benfanti P, Blackhurst DW, Allen BL. Assessment of femoral anteversion in children with cerebral palsy: accuracy of the trochanteric prominence angle test. J Pediatr Orthop. 2002;22(2):173–8.
22. Reimers J. The stability of the hip in children. A radiological study of the results of muscle surgery in cerebral palsy. Acta Orthop Scand Suppl. 1980;184:1–100.
23. Kalen V, Bleck EE. Prevention of spastic paralytic dislocation of the hip. Dev Med Child Neurol. 1985;27(1):17–24.
24. Sink EL, Leunig M, Zaltz I, Gilbert JC, Clohisy J. Reliability of a complication classification system for orthopaedic surgery hip. Clin Orthop Relat Res. 2012;470(8):2220–6.
25. Dindo D, Demartines N, Clavien P-A. Classification of surgical complications. Ann Surg. 2004;240(2):205–13.
26. Flynn JM, Miller F. Management of hip disorders in patients with cerebral palsy. J Am Acad Orthop Surg. 2002;10(3):198–209.
27. DiFazio R, Shore B, Vessey JA, Miller PE, Snyder BD. Effect of hip reconstructive surgery on health-related quality of life of non-ambulatory children with cerebral palsy. J Bone Joint Surg Am. 2016;98(14):1190–8.
28. Cooke PH, Cole WG, Carey RP. Dislocation of the hip in cerebral palsy. Natural history and predictability. J Bone Joint Surg Br. 1989;71(3):441–6.
29. Schoenecker PL, Anderson DJ, Capelli AM. The acetabular response to proximal femoral varus rotational osteotomy. Results after failure of post-reduction abduction splinting in patients who had congenital dislocation of the hip. J Bone Joint Surg Am. 1995;77(7):990–7.

30. Spence G, Hocking R, Wedge JH, Roposch A. Effect of innominate and femoral varus derotation osteotomy on acetabular development in developmental dysplasia of the hip. J Bone Joint Surg Am. 2009;91(11): 2622–36.

31. Chang FM, May A, Faulk LW, Flynn K, Miller NH, Rhodes JT, et al. Outcomes of isolated varus derotational osteotomy in children with cerebral palsy hip dysplasia and predictors of resubluxation. J Pediatr Orthop. 2016 [Epub ahead of print] PubMed PMID: 27280898.