



Conventional versus locked plates for hip dislocation in cerebral palsy: a matched cohort analysis

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Abstract

Purpose Bone quality of non-ambulatory patients with cerebral palsy (CP) is a matter of concern for proximal femoral varus derotational osteotomies (VDRO). Locking plates (LCP) have been designed to compensate this biological downfall. Little data exist comparing the LCP with the conventional femoral blade plate.

Methods We retrospectively studied 32 patients submitted to VDRO (40 hips), operated with blade plates or LCP. Groups were matched, and the minimal follow-up was 36 months. Clinical (age at surgery, sex, GMFCS class, CP patterns) and radiological characteristics (neck shaft angle [NSA], acetabular index [AI], Reimers migration index [MP] and time until bone healing), as well as postoperative complications and the cost of treatment, were evaluated.

Results Preoperative clinical characteristics and radiographic measurements were comparable, except for a higher AI in the BP group ($p < 0.01$). Mean follow-up was longer in the LCP group (57.35 vs 34.6 months). Mean NSA, AI and MP had comparable correction with surgery ($p < 0.01$). At final follow-up, dislocation recurrence speed was higher in BP group although not statistically significant (0.56% vs 0.35%/month; $p = 0.29$). The complication rate was similar in both groups ($p > 0.05$). Finally, the cost of the treatment was 62% higher in the LCP group ($p = 0.01$).

Conclusion Our cohorts showed LCP or BP equivalence clinically and radiographically in mid-term follow-up, with the former increasing the cost of treatment by a mean of 62%. This may raise a question on the real necessity of locked implants for these operations.

Level of evidence Level III—Retrospective comparative study.

Keywords Cerebral palsy · Hip dislocation · Osteotomy · Femur · Recurrence

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Introduction

Hip dislocation in cerebral palsy (CP) is frequently associated with pain, seating and perineal hygiene difficulties and consequent deterioration of mobility and quality of life [1–4]. Patients with worse functional patterns, especially grades IV and V in the gross motor function classification system (GMFCS) [5], are at higher risk for hip dislocation, which occurs in up to 70 and 90%, respectively [2–4]. The prevention of hip displacement in patients with CP has therefore been addressed in several hip surveillance programs internationally, where patients get personalized outpatient sequential physical and radiological examinations, leading to surgical treatment as needed, with high success rates [6–9].

Part of the prevention strategy involves early identification of patients at risk and surgical procedures addressing soft tissue or bone. Femoral varus derotation osteotomy (VDRO) is the main bone operation performed in the paralytic hip for this purpose, traditionally using the fixed angle blade plate (BP) [6, 10, 11]. However, poor bone quality is prevalent in the non-ambulatory CP population, creating a concern regarding the stability of fixation with the aforementioned implant [12, 13]. Consequently, locking plates (LCP) were developed to try to minimize the risk of implant failure in this fragile population, optimizing stability and avoiding reoperations. LCP have been used since their development in many orthopedic centers specialized in the treatment of CP patients [14–17].

There is scarce evidence in the literature about the clinical and radiological benefits of the use of LCP when compared to conventional BP [14]. A small number of studies has evaluated the outcomes of VDROs using locking plates in case series or compared them in biomechanical testing to the BP. While clinical comparisons yielded similar outcomes and safety with both implants, biomechanical tests showed more stiffness in plates with locking screws in the proximal fragment and also increased pullout strength in these constructs [15, 16, 18–22]. Mid-term comparisons between those two implant groups are lacking and are the main objective of the present study. We evaluated the recurrence of dislocation and proximal femoral deformity as well as the complications and cost of treatment with both systems.

Materials and methods

After approval by the institutional ethics committee (CAAE 73475217.2.0000.5249), we retrospectively retrieved from medical charts the data related to

non-ambulatory CP patients submitted to proximal femoral VDRO in our hospital from June 2013 to December 2016. All patients were classified as GMFCS IV or V, and the operation was isolated or part of a multilevel intervention (SEMLS—single event multilevel surgery) as recommended for the treatment of patients with CP-related multiple contractures [23, 24]. Parental informed consent was obtained for all the operations. Patients that were lost to follow-up for any reason before 36 months of the index operation, as well as those with an extrapyramidal pattern of CP and patients with incomplete data available, were excluded from our study.

To determine the sample size needed for a statistically relevant evaluation, the first step was to determine the margin of error considered in our sample. For that purpose, as Brazilian population data are unavailable on the prevalence of cerebral palsy, we utilized data from a well-established and documented CP register, the Victorian cerebral palsy register (VCPR). According to that source, 35% of CP children will present hip dislocation during their lifetime. In our complete sample, before matching, the average migration percentage (MP) was 69.94% with a standard deviation (SD) of 29.74%, which represented 42.5% of the average. That number was used as margin of error for the calculation of the sample size. Therefore, for a confidence level of 99.99%, a margin of error of 42.5% and a proportion of 35% of patients with CP that have hip displacement, a minimum sample size of 18 was indicated. Out of our previously published cohort of 61 patients [25] operated with the LCP, a matching group was created from an historical cohort of CP patients operated with conventional plates, regarding GMFCS level and age at surgery. This aimed at diminishing the probability of a selection bias and a final sample of 16 patients (20 hips) in each studied group was reached.

Preoperative and intra-operative data included age, sex, geographic classification of CP (diplegic, triplegic and tetraplegic), implant used (LCP or BP) and functional classification (GMFCS level). Radiographic measurements were performed by a fellowship trained pediatric orthopedic surgeon, in standardized anteroposterior (AP) pelvis radiographs with the lumbar spine flattened on the bed, compensating for hip flexion contractures, a coronally leveled pelvis correcting adduction or abduction deformities and neutral rotation of the hips [9]. Measurements included the neck shaft angle (NSA), the acetabular roof index (AI) and the Reimers lateral migration percentage (MP) [26] along with the time until radiographic healing of the osteotomy. The latter was considered when three out of four cortices presented bone callus bridging the osteotomy site or when the site was not visible. All measurements were performed in a validated orthopedic software (Bone Ninja™, International Center for Limb Lengthening, Baltimore, MA, USA).

The surgical technique for femoral VDRO was performed as previously described in the literature [16, 27, 28]. All patients in each group were operated using the same plates and screws, consisting in 90° 3.5-mm angled blade plate (Synthes, Oberdorfen, Germany) for the BP group and 100° or 110° locked screw plate in the LCP group (Synthes, Oberdorfen, Germany). Patients were immobilized postoperatively in a spica cast when the VDRO was associated with a pelvic osteotomy. When the VDRO was isolated or associated only to soft tissue surgery, a bilateral synthetic polyester inguino-malleolar cast (Hygia Cast, Woosam Medical, Paju-Si, South Korea) with an abduction bar (broomstick) was the choice for postoperative care. The child was reviewed in the outpatient clinic every two weeks, discontinuing the cast when initial callus formation was radiographically appreciated.

The duration of the operation was registered in minutes, considering the time from initial skin incision until the end of postoperative cast immobilization.

The cost of treatment was registered for each patient and included the hospital costs related to the VDRO operation and hospital stay, as well as all additional costs involved in the subsequent admissions, for cast removal or changes, reoperations and complications related to the index operation. Hospital costs included medical fees, implant costs, hospital supplies and medications.

Complications were graded according to the Clavien–Dindo (CD) classification [29], where grade I complications do not require changes in the conventional treatment, grade II require outpatient-based modifications, grade III require radiological or surgical interventions, grade IV are associated with long-term morbidity, and grade V result in patient death [30].

Qualitative data were expressed by absolute and percentual frequencies, while quantitative data were expressed by averages, standard deviations, minimum, maximum and median values. Comparisons between cohorts and times used a linear regression model with mixed effects (random and fixed). These are used for analysis in grouped answers when the supposition of independence between observations in the same group is not adequate. They presuppose normal distribution and constant variance. When such presupposition is not observed, transformations of the response variable were performed. Comparisons used orthogonal contrast post-test, and all models were controlled for follow-up and AI (possible confusion factors). Statistical analysis was done with SAS 9.2 software (SAS Institute, North Carolina, USA) and graphics with the software R, version 3.4.1 (R Foundation for Statistical computing, Vienna, Austria). Significance level of 5% was used for all comparisons ($\alpha=0.05$).

Table 1 Demographic characteristics of the study population

	LCP	BP
Age in years (mean (SD))	8 (2.6)	7.5 (2.63)
Follow-up in months (mean (SD))	57.35 (9.79)*	34.6 (3.83)*
<i>Side</i>		
Right	10	8
Left	10	12
GMFCS 4	2	2
GMFCS 5	18	18
<i>Motor pattern</i>		
Spastic	18	19
Mixed	2	1
<i>Surgical technique</i>		
VDRO	11	10
VDRO + OR	2	2
VDRO + Dega	1	1
VDRO + OR + Dega	6	7

LCP locking compression plate; *BP* blade plate; *SD* standard deviation; *GMFCS* gross motor function classification scale; *VDRO* varus derotational osteotomy; *OR* open reduction; *Dega* Dega acetabuloplasty

* $p<0.05$

Table 2 Preoperative radiographic comparison between groups

Parameters (Mean (SD))	LCP	BP	<i>p</i> -value
NSA (°)	153.65 (10.49)	156.9 (11.31)	0.95
AI (°)	20.45 (6.19)	24.45 (5.94)	<0.05
MP (%)	63.1 (32.68)	69.95 (32.55)	0.05

SD standard deviation; *LCP* locking compression plate; *BP* blade plate; *NSA* neck shaft angle; *MP* migration percentage

Results

Both the blade plate and the LCP groups consisted in 16 patients and 20 hips submitted to proximal femoral VDROs. Associated procedures were present in 50% of the blade plate group and 45% of the LCP group, being the most common combination of bone procedures a VDRO associated with Dega acetabuloplasty and open reduction in the hip. The latter was present in 35% of the blade plate group and 30% of the LCP group. Ages were similar between groups ($p>0.05$), with a mean of 8 (± 2.6) years in the LCP group and 7.5 (± 2.63) in the BP group. Follow-up was longer in the LCP group, with 57.35 months versus 34.6 in the BP group. Moreover, side distribution, geographic classification and motor pattern were similar between groups, as well as GMFCS classification. Main demographic findings are given in Table 1.

Table 3 Preoperative versus postoperative radiographic changes between groups

Parameters (mean)	LCP			BP		
	Pre-op	Immediate post-op	Late post-op	Pre-op	Immediate post-op	Late post-op
NSA (°)	153.65	118.75*	122.5*	156.9	115.11*	113.6*
AI (°)	20.45 [#]	16.2* [#]	16.45* [#]	24.45 [#]	20.5* [#]	19.45* [#]
MP (%)	63.1	5.3*	24.25* ^o	69.95	2.9*	22.08* ^o

LCP locking compression plate; BP blade plate; NSA neck shaft angle; AI acetabular index; MP migration percentage; Pre-op preoperative value; Post-op postoperative value

[#] $p < 0.05$ between LCP and BP group measures; * $p < 0.05$ between pre- and postoperative measures;

^o $p < 0.05$ between immediate and late postoperative measures

The radiographic parameters analyzed included NSA, AI and MP, preoperatively, immediately after the operation and at the latest follow-up. LCP and BP groups were compatible preoperatively when considering NSA and MP ($p > 0.05$) but AI was statistically higher in the BP group ($p < 0.01$). When considering the correction obtained with the operation, both groups showed correction of all parameters after the osteotomies ($p < 0.01$). Comparisons between groups are highlighted in Tables 2 and 3.

The amount of correction achieved with index operation was similar between LCP and BP groups, for NSA ($p = 0.1$), AI ($p = 0.92$) and MP ($p = 0.43$). Moreover, the difference between preoperative and late postoperative values was also compatible for NSA ($p = 0.12$), AI ($p = 0.65$) and MP ($p = 0.44$).

When comparing groups regarding subluxation relapse during follow-up, we found that for LCP, we had a mean MP progression of 0.35% per month; meanwhile, the BP group MP progressed at a 0.56% rate per month. The difference between groups was not significant, with a p -value of 0.29 using Student's t test.

Operative time was in average 178.43 ± 58.94 min in the LCP group and 192 ± 22 min in the BP group. This difference was not statistically significant ($p = 0.26$).

Complications were present in six (30%) patients in the LCP group and seven (35%) in BP group ($p > 0.05$). Grade II complications were present in two patients in the LCP group and three in the BP group and consisted in pressure sores in sacral and calcaneal regions. Complications requiring orthopedic intervention, classified as CD III, were present in two patients in the LCP group and consisted in one screw unlocking from the plate and one non-union. Meanwhile, in the BP group, one patient had reoperation for redislocation. There were two grade IV complications in the LCP group, consisting in pneumonia and intestinal obstruction, compared to three in the BP group (aspiration pneumonia, urinary tract infection and renal failure), requiring prolonged hospitalization.

Finally, the cost was significantly different among the studied groups, higher in the LCP group ($p = 0.01$). Mean

treatment cost was BRL 9019.43 (± 3821.01) for LCP and 5635.94 (± 2291.5) for BP, configuring an increase of 62% when using the LCP instead of the BP.

Discussion

We have compared the main radiological outcomes, complications, and costs of two matched cohorts of non-ambulatory CP patients undergoing femoral VDROs using two different implants, the conventional angled blade plate and the LCP pediatric hip plate. We found no difference in radiological correction of NSA and MP with both implants, which were also compatible in their complication rate and subluxation recurrence speed. However, the cost of treatment with a locked implant was in average 62% higher than the cost with conventional plates.

To the best of our knowledge, this is the second study to compare cohorts of CP patients submitted to VDROs with both implants [15], and the first to have a radiographic correction comparison and cost analysis backing the clinical outcomes.

The previously published work that compared both implants found similar results in terms of radiographic outcome at short follow-up, even though a slower healing speed with the LCP. We did not find any differences in terms of healing between implants, with a longer follow-up when compared with the aforementioned paper [15].

In terms of radiographic correction, Khouri et al. [16] published a cohort of 59 operated hips with the LCP, and the mean NSA and MP were compatible with our findings preoperatively, showing consistency in the population characteristics and surgical indication. However, they did not include AI considerations, even though more than half of their patients had an associated pelvic osteotomy. Moreover, ambulatory and non-ambulatory patients were included, which can confound the results, as the literature shows the evolution of paralytic hip dislocation to be very diverse between both populations [3, 6, 31]. Therefore, our cohort is more homogenous and radiographic analysis

more complete, as we included all radiographic parameters relevant to proximal femoral and acetabular morphology in cerebral palsy, allowing for a more precise interpretation of the results.

Patients from both groups had similar characteristics preoperatively, except for a higher AI in the BP group, taken into consideration in the statistical analysis, and a shorter follow-up in the same population. However, this may not have had impact in the outcome analysis, especially if we consider the recurrence speed, which had no statistical difference in the duration of the study ($p=0.29$). Nevertheless, it is important to acknowledge that this speed was higher in the BP group, and the mean MP at final follow-up was similar between groups even with a shorter follow-up in the BP group. One can hypothesize that a longer follow-up or a larger sample of the BP group would invariably lead to more recurrence of dislocation, which would be concurrent with the literature that defends residual dysplasia as an important factor in hip redislocation [32–34]. The recurrence speed was higher when compared to previously published data, with 4.5% MP progression per year in the LCP group and 6.72% in the BP hips. Sung et al. found 1.6%/year MP progression in their group of dislocated hips undergoing VDROs [34]. Our group previously published the results of 61 hips submitted to VDROs with the LCP and found a mean recurrence speed of 2.54%/year in the patients that redislocated during follow-up [25]. The higher speed in the present cohorts may raise concern regarding the intrinsic characteristics of our population, and a larger group analysis might help diminishing this confounding factor.

Operative time was higher in the BP group, and even though it was not statistically significant, it reinforces the impression of some surgeons and trainees that the locked plates are more reliable and the technique more reproducible, which might decrease the operative duration [14]. In contrast, Rutz et al. identified a longer operative time in their LCP group, with statistical relevance.

The cost analysis brought important information, especially considering the implementation of this implants in public health and developing countries. Determining no clinical superiority might question the need for such expensive implants. However, we recognize that our cohorts are not large enough for definitive conclusions on that matter. One should also consider that since the analysis of these data, more companies have designed and commercialized similar implants, which could lower the costs of treatment. Moreover, the technical aspect is also important, especially during early surgeon training, and cannulated plates and screws help reproducing results and positioning, particularly in the poor bone quality seen in CP [14].

Finally, our study presented some limitations, inherent to the retrospective design, and to the size of the population

evaluated. They were surpassed by a comprehensive statistical analysis, with sample sizing, matching and confounding factor exclusion, but more patients are currently being added to the cohorts, to improve data quality. Strong points included the homogenous characteristics of both groups, allowing for a credible comparison of radiographic parameters along a minimum 3-year follow-up, and the cost analysis, not previously performed for this operation.

In conclusion, our cohorts showed LCP or BP for femoral VDROs in non-ambulatory CP patients to be equivalent clinically and radiographically, with the former increasing the cost of treatment by a mean of 62%. This may raise a question on the real necessity for locked implants for these operations.

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Author contributions All authors contributed to the study conception and design. Material preparation and data collection were performed by FCMV, HAC, VMV and MVF. Data analysis was performed by FCMV and HAC. The first draft of the manuscript was written by FCMV, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability All patient anonymized data are available as supplementary material and can be shared upon request in other formats.

Declarations

Conflicts of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethics approval Ethical approval was waived by the local Ethics Committee of Instituto D'Or de Ensino e Pesquisa, in view of the retrospective nature of the study, and all procedures being performed were part of the routine care. Approval number was CAAE 73475217.2.0000.5249.

Consent to participate All patient parents signed written informed consent to participate in the study.

Consent to publish No consent to publish was necessary because all patient data was anonym and blinded to the authors, and no patient image was published.

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