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Closed reduction evaluation in dysplastic hip with the Ömeroğlu system in children aged 24 to 36 months

Sergio Charles-Lozoya, M.Sc[a,b,*], Salvador Chávez-Valenzuela, MD[a], Héctor Cobos-Aguilar, PhD[b], Edgar Manilla-Muñoz, PhD[b], Miguel Leonardo De La Parra-Márquez, M.Sc[a], Héctor Eliud Arriaga-Cazares, M.Sc[a], Adrián García-Hernández, MD[a]

Abstract

Closed reduction (CR) as an initial treatment for developmental hip dysplasia of the hip (DDH) in children aged 24 to 36 months is debatable; however, it could have better results than open reduction (OR) or osteotomies, because it is minimally invasive. The purpose of this study was to evaluate the radiological results in children (24–36 months) with DDH initially treated with CR. Initial, subsequent, final anteroposterior pelvic radiological records were retrospectively analyzed. The International Hip Dysplasia Institute was used to classify the initial dislocations. To evaluate the final radiological results after CR (initial treatment) or additional treatment (CR failed), the Ömeroğlu system was used (6 points excellent, 5 good, 4 fair-plus, 3 fair-minus, and ≤2 poor). The degree of acetabular dysplasia was estimated using the initial acetabular index and the final acetabular index, Buchholz–Ogden classification was used to measure avascular necrosis (AVN). A total of 98 radiological records were eligible, including 53 patients (65 hips). Fifteen hips (23.1%) were redislocated, OR with femoral osteotomy and pelvic osteotomy was the preferred surgical treatment 9 (13.8%). The initial acetabular index versus final acetabular index in total population was (38.9° ± 6.8°) and (31.9° ± 6.8°), respectively (t = 6.5, P < .001). The prevalence of AVN was 40%. Overall AVN in OR, femoral osteotomy and pelvic osteotomy were 73.3% versus CR 30%, P = .003. Unsatisfactory results ≤ 4 points on the Ömeroğlu system were observed in hips that required OR with femoral and pelvic osteotomy. Hips with DDH treated with CR initially might had better radiological results than those treated with OR and femoral and pelvic osteotomies. Regular, good, and excellent results, ≥4 points on the Ömeroğlu system, could be estimated in 57% of the cases, in whom CR was successful. AVN is frequently observed in hips with failed CR.

Abbreviations: AP = anteroposterior, AVN = avascular necrosis, CR = closed reduction, CTD = center-trochanter distance, DDH = developmental dysplasia of the hip, FAI = final acetabular index, FO = femoral osteotomies, H = hilgenreiner, IAI = initial acetabular index, ICC = intraclass correlation interval, IHDI = International Hip Dysplasia Institute, OR = open reduction, PO = pelvic osteotomies.

Keywords: congenital dislocation of the hip, closed reduction, open reduction, redislocation, femoral head necrosis, walking age children

1. Introduction

Developmental dysplasia of the hip (DDH) consists of a broad range of hip disorders, involving pathological modifications due to the inability of the femoral head to maintain an adequate position within the acetabulum, with ranges of gravity, from mild acetabular dysplasia without hip dislocation to full hip dislocation,[1–3] and irregularities in the constitution of the femoral head. It has an incidence of 1% to 7% in newborns, varying due to genetic susceptibility and race from 0.06% in Africans to 76.1% in Native Americans.[4] The objective of treatment is to achieve concentric reduction of the femoral head towards the acetabulum, which allows the correct development of all hip structures.[5] Although there is variability in

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[a] Health and Research Science Management, Pediatric Orthopedic Surgery, Division of Plastic and Reconstructive Surgery, Hospital de Traumatología y Ortopedia No. 21, Instituto Mexicano del Seguro Social (IMSS). Monterrey, N.L., México, [b] Health Science Division, Vice-rectory of Health Science, Universidad de Monterrey, San Pedro Garza Garcia N.L., México.

** Correspondence: Sergio Charles-Lozoya, Health and Research Science Management, Pediatric Orthopedic Surgery, Division of Plastic and Reconstructive Surgery, Hospital de Traumatología y Ortopedia No. 21, Instituto Mexicano del Seguro Social (IMSS), Av. José MA. Pino Suárez y Juan Ignacio Ramon, 10th floor. downtown, ZIP 64000 Monterrey N. L., Mexico (e-mail: scharleslozoya@yahoo.com.mx).*

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treatment protocols, their choice depends on patients ages.[6] Closed reduction (CR) plus immobilization with a plaster cast could be appropriate management in patients younger than 24 months,[7] while open reduction (OR) with pelvic osteotomies (PO) might be the treatment of choice in older patients.[8] However, results and comparisons of CR and OR plus PO in patients aged 18 to 36 months, appear to have equivalent and not well-defined or discrepant long-term results.[9] Thus, children of these ages are still disputable if CR increases the probability of avascular necrosis (AVN) or unsatisfactory radiological results. In children older than 4 years who are undergoing OR and PO, the risk of AVN is high, with poor clinical and radiological results.[10] In contrast, rates of AVN in children ≥ aged 3 years and treated with OR and PO are like those in children ≤ 3 years.[11] Therefore, handling of patients aged between 1 and 5 years remains controversial and may include CR first, OR, and PO late, but children older than 3 years, are dubious to achieve a fruitful result with CR.[12]

Radiological results with CR in patients aged 24 to 36 months are limited and controversial, but with scarce resources, high demands for health care, and a late diagnosis of DDH, management is a challenge, which is why less invasive treatments are used, but it is necessary to provide evidence for their results. Therefore, the main objective of this study was to evaluate the radiological results of children with DDH, amid 24 to 36 months treated with CR, and our secondary purpose was to evaluate those children in whom CR failed and needed OR, PO, femoral osteotomies (FO), or all.

2. Methods

2.1. Patients

During the years 2020 to 2021, an analysis of radiological records was carried-out in the Pediatrics Orthopaedics Service of the High-specialty Medical Unit of the Trauma and Orthopaedics Hospital No. 21 in Monterrey, Mexico of the Mexican Institute of Social Security. The protocol was approved by the research and ethics committees of the unit (#*R*-2020-1903-012, date: September 17, 2020), and patients were included in the study after obtaining written consent from their parents. The radiological records of children aged 5 years and over were included, with radiological follow-up of more than 2 years of evolution, with at least 1 pretreatment radiograph and an annual anteroposterior (AP) plain pelvic radiograph. All patients were initially treated with CR for DDH and were aged 24 to 36 months at the time of treatment (diagnosis made by the treating pediatric orthopedist, when plotting with the help of System Webserver® Perkin and Hilgenreiner lines and observing the femoral head outside the inferior and internal quadrant of Putti) (Fig. 1a). Children with spastic hip, paralytic hip, history of amyoplasia, neuromuscular syndrome, or other congenital malformations, and those treated with OR initially were excluded. Sample Selection: Through nonprobabilistic sampling of consecutive cases, 53 radiological records (65 hips) were obtained from the unit's annual record of surgical procedures from 2012 to 2017.

2.2. Radiological scales

International Hip Dysplasia Institute (IHDI) is a radiographic classification system for initial evaluation of DDH, which takes as reference the hilgenreiner (H), Perkin lines (start from the triradiate cartilage and the outermost edge of the acetabulum, respectively), diagonal, and H point. Ramo[13] estimates an intraclass correlation interval (ICC) of 0.90 to 0.95 (Fig. 1a). Ogata "*refined*" CE Angle,[14] that evaluates bone condensation of the acetabular roof with a line that was drawn from the center of the metaphysis of the femoral neck, parallel to the longitudinal body axis and another line to the most lateral portion of said bone condensation (Fig. 1e), Ömeroğlu refers a reproducibility (κ= 0.54–0.76).[15] Buchholz–Ogden classification[16] to graduate AVN of the proximal femoral epiphysis AVN and includes type I: irregular ossification of the femoral head, II: lateral epiphyseal closure, valgus deformity of the head on the femoral neck, III: necrosis in the physis with growth alteration in the entire physis, IV: early closure of the medial physis with varus deformity, Roposch[17] refers a κ= 0.34 to 0.61. Acetabular index was estimated with initial acetabular index (IAI) and final acetabular index (FAI), by taking the H line as reference and a diagonal line up to the outer edge of the acetabular roof. They were measured twice, and the average was taken as the final measurement.

To quantify the main radiological results, the radiographic classification outcome system used "Ömeroğlu,"[18] which includes 3 measurements, the center edge angle of Wiberg, the

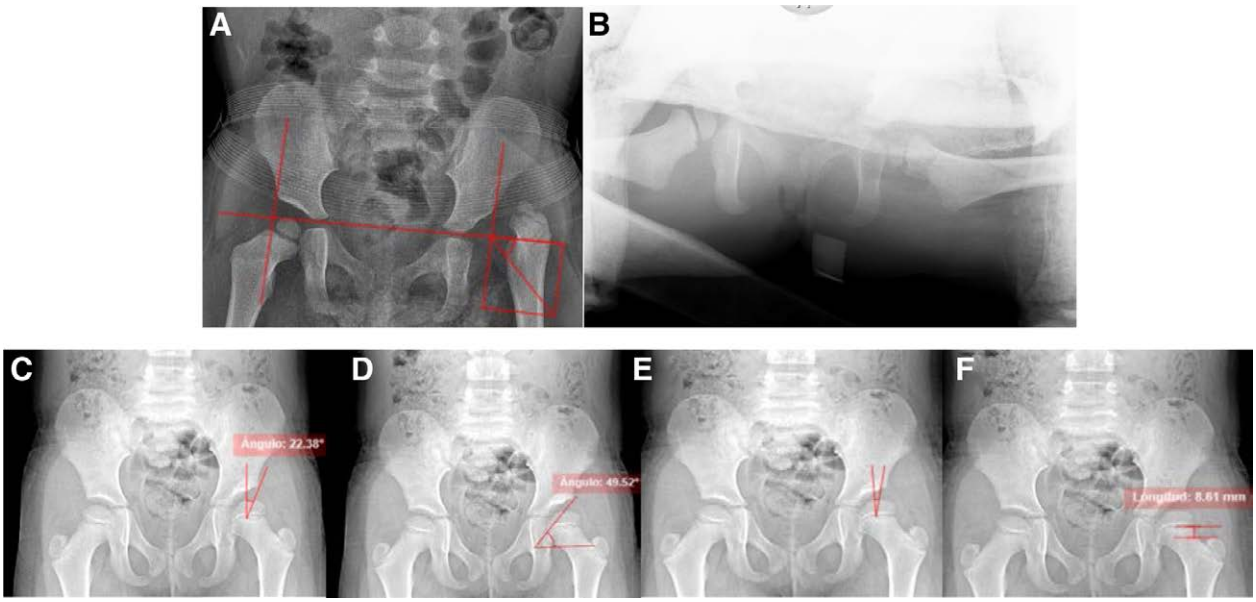

Figure 1. 34-month-old girl with IHDI grade IV left DDH, treated with CR (a, b). Evaluation using the Ömeroğlu system at 7 years. Wiber, Sharp and Ogata Angles (c–e). Center-Trochanter Distance (f). Obtained 5 points for satisfactory results. DDH = developmental dysplasia of the hip, IHDI = International Hip Dysplasia Institute.

acetabular angle of sharp, the center-trochanter distance (CTD), as well as 3 modifiers: the Ogata angle grade IV, the need for secondary treatment and the redislocation (Fig. 1 a–f). The score ranges fluctuated between 1 and 6 points and were considered satisfactory in hips with ≥ 5 points. Ömeroğlu[19] reported an inter and intraobserver reliability of 0.81 and 0.88, respectively.

2.3. Radiological evaluation

This was performed by the main author of this report (pediatric orthopedic surgeon) when analyzing the initial radiograph, annual subsequent, and last AP of the pelvis. By means of the definitions and diagrams of each classification, radiological measurements were made, and radiological files were analyzed with the help of the System Webserver®. The intra-observer consistency of the measurements was estimated by the main author, blinded to the evolution of the patients 6 weeks after the first evaluation, using Cohen Kappa (κ), weighted Kappa and ICC, the images were reordered randomly and without clinical information of the subjects. The measurement of the center edge angle of wiberg, acetabular angle of sharp, CTD angles, as well as the IAI and FAI obtained an ICC that ranged between 0.85 to 0.98. For the Ogata Angle, AVN and IHDI the weighted Kappa was estimated and was (κ= 0.76, 0.74, and 0.71), respectively. Redislocation was confirmed if the femoral head was observed out of the quadrant inferior and internal of Putti (Drawing the lines of Perkin, Hilgenreiner and Shenton).

2.4. Surgical procedure

Initial CR was performed on all 65 hips in accordance with the hospital protocol, skin traction was not performed in any case. CR was performed under general anesthesia, tenotomy of the adductor group was performed in all cases. The reduction was confirmed by observing the femoral head in the acetabulum inside the inferior and internal quadrant of Putti, (the evaluation was done retrospectively by observing the radiological images by 2 pediatric orthopedists to obtain a Cohen Kappa κ= 0.85). In addition, they were considered the following criteria: A. Good reduction if: Shenton line intact with legs in neutral position; < 2 mm discrepancy compared with the contralateral hip of the distance from the inner acetabular cortex to the medial corner of the femoral methaphysis in unilateral cases; Femoral methaphysis directed toward triradiate cartilage on abduction radiographs; and reduction stable we the safe zone of Ramsey. B. Adequate reduction (mild lateralization) if: Shenton line intact or slightly broken with legs in neutral position; a discrepancy of 2 to 5 mm in the distance from the inner acetabular cortex to the medial corner of the femoral methaphysis in unilateral cases; femoral methaphysis directed toward triradiate cartilage on abduction radiographs; and reduction stable we the safe zone of Ramsey.[20] Subsequently, a hip spica plaster cast was placed in a human position at 90° flexion, 45° abduction and slight internal rotation, with gently elevation of the greater trochanter like an Ortolani movement, applying slight force.[21] At 6 weeks an AP radiograph of the pelvis was taken to asses hip reduction (the assessment was retrospective by 2 pediatric orthopedists and obtained a Cohen Kappa [κ= 0.83], if it was considered reduced, sedation was scheduled, a new hip spica plaster cast was then placed in lange "second" position knees extended, 45° abduction, and maximum internal rotation),[22] but if a redislocation was observed the surgeon decided according to his judgment and experience to operate OR, and add FO, PO or all. In the outpatient clinic, 6 weeks later, the previous plaster cast was cut slightly above the knee, and its use was continued for another 6 weeks, until its removal (it works like a full-time abduction bar), if the parents had resources to order a rigid custom-made abduction brace, it was used for 1 year, with the hip flexed and abducted at 90° and 45° respectively. In the subsequent consultations, the surgeon evaluated residual dysplasia like the acetabular angle FAI, femoral anteversion, AVN or any sequelae and decided on FO, and PO at his judgment and experience.

2.5. Statistical methods

Cohen (κ) and weighted Kappa index were calculated, as well as ICC, respectively to determine the consistency of the measurements. For the comparative analysis of quantitative variables, Student's t, Mann–Whitney *U*, ANOVA or Kruskal–Wallis tests were used according to the assumptions of normality and homoscedasticity of variances; Pearson χ^2 test for comparison of frequencies and percentages of dichotomous qualitative variables. A value of $P < .05$ was considered significant. The analysis was performed with the SPSS version 24 program (SPSS, Chicago, IL).

3. Results

We reviewed 98 hip radiological records; 18 hips did not have a complete radiological record, and 15 hips were under 5 years of age to apply the Ömeroğlu system. Thus, 65 hips (53 subjects) were included in this study. Forty-nine were women (92.5%), with a predominance of the left hip in 38 cases (58.5%). IHDI grade II occurred in 25 (38.5%) hips. Femoral head ossific nuclei were evident in 61 (93.1%) hips. Of the participants, 76.9% did not require surgical treatment. During follow-up, 15 hips were redislocated (23.1%), 8 were bilateral, and 7 were left (87.5%) ($\chi^2 = 15.5$, $P < .001$). OR and femoral and pelvic osteotomies were performed in 13.8% of the total population. The follow-up was R:32 to 80 months. (Table 1).

In contrast, the IAI and FAI between the groups of subjects who underwent only CR versus those who underwent only OR, OR plus FO, OR plus PO or all, and did not show differences. Nevertheless, when comparing the IAI versus FAI in the entire population, the IAI (38.9 °±6.8°), as well as the FAI (31.9 °±6.8°), differences were obtained ($t = 6.5$, $P < .001$). The prevalence of AVN was 40% in the total population. The AVN prevalent was type 2 in subjects only with CR 6 (12%), type 3 was equal in subjects who received CR and those in whom was required OR, FO and PO 4 (6.2%), prevalence of AVN was 30% in the CR group. The final radiological evaluation carried-out in the 4 groups with the Ömeroğlu system, which measured the Wiber and Sharp Angles and CTD, the CTD had differences ($P = .04$), with less relative overgrowth of the greater trochanter in the CR group. The post hoc analyses showed differences in the Sharp Angle among the (CR 46.3° vs OR 51.3°) ($P < .001$). Regarding the type of Ogata acetabulum, type III was prevalent and was observed in 31 hips (47.7%). Ogata type IV acetabulum (lower coverage) in subjects who underwent CR failed and then received OR, FO and acetabuloplasty was 77.8%, while 54% in subjects who only received CR had Ogata type III and showed differences between groups. (Table 2).

With the radiological evaluation using the Ömeroğlu system in the CR group, regular, good, and excellent results were obtained in 37 hips (57%), 25 hips in total population (38.5%) showed 3 points (poor) or less, with a predominance of 4 or less points (unsatisfactory) in hips with CR failed and need surgical treatment like OR, and FO and acetabuloplasty or all. The Ömeroğlu score of 5 points or more (satisfactory results) in CR was (32%) and differences were observed respect OR, FO and PO ($P < .001$). (Fig. 2).

4. Discussion

The main finding of this report was the frequency of AVN observed in the group of subjects who received OR, FO and PO treatment (7 of 9 hips) in whom CR failed and required surgery. In

Table 1

Clinical and radiological descriptions of patients with developmental dysplasia of the hip who underwent initial closed reduction.

Characteristic		n = 65
Patient		53 (65 Hips)
Sex (%)		
Men		4 (7.5)
Women		49 (92.5)
Affected side (%)		
Right		15 (28.3)
Left		26 (49.1)
Bilateral		12 (22.6)
Initial treatment age, mo, median, IQR		24 (24–26)
Final evaluation age, mo, median, IQR		67 (62–72)
Follow-up, mo, median, IQR		42 (37–48)
Redislocation (%)		15 (23.1)
Ossific nucleus (%)		61 (93.8)
IHDI (grades) (%)	1	21 (32.3)
	2	25 (38.5)
	3	5 (7.7)
	4	14 (21.5)
Initial acetabular index, mean, SD		38.9º ± 6.79º
Final acetabular index, mean, SD		31.9º ± 6.8º
Types of treatments (%)	CR	50 (76.9)
	OR	3 (4.6)
	OR + FO	3 (4.6)
	OR + FO + PO	9 (13.8)
AVN femoral epiphysis, grades (%)	0	39 (60)
	1	3 (4.6)
	2	9 (13.8)
	3	11 (16.9)
	4	3 (4.6)

CR = close reduction, FO = femoral osteotomy, IHDI = International Hip Dysplasia Institute, IQR = interquartile range, OR = open reduction, PO = pelvic osteotomy, SD = standard deviation.

high prevalence of AVN (55%) in children undergoing OR, but without previous CR treatment,[24] OR in walking children aged > 28 months could be a prognostic factor for poor results. In our study, the high prevalence of AVN in hips that required surgical treatment prior to CR could be due to age; nonetheless, it does not resolve the question of whether age is the principal factor for AVN, if previous CR is hazardous and increases the risk of AVN, or if subjects in whom CR failed were more pathologic and potentially the attempted CR treatment might produce harm. A report comparing children ≤ 18 months versus ≥18 months of age found that age at reduction has no effect on the risk of AVN after CR is performed, inclusive in subjects ≥ 18 months.[25] Another possible reason to the high frequency of AVN in subjects who had invasive treatment, mainly due to redislocation, might be associated with previously CR and overall, with higher degree of acetabular dysplasia, advanced age, and the undue pressure on the femoral head, occurring when high dislocations are reduced and prereduction traction was not used, they all could be associated and predispose to AVN and redislocation. We did not use traction, although there is some discrepancy between whether skeletal traction is used or not, as reported by Yi-Qiang Li,[26] since in his study, he did not find a significant difference in hips treated with CR, with and without traction as a risk factor for AVN.

An interesting aspect that we noticed in our results is that we studied 12 cases with both hips dislocated; only 1 had satisfactory results, 8 of these had redislocation after CR, 7 were left, and a point to analyze was if when DDH was bilateral, the left side was more dysplastic and influenced redislocation. Furthermore, initial CR in bilateral cases could compromise the effect of the secondary treatment and be a risk factor for AVN, which gives foot to future reports that analyzed and selected patients to provide recommendations and stricter parameters on which patients should not achieve CR after 24 months of age.

Regarding the evaluation of the radiological results, when estimating and comparing the type of Ogata acetabulum,

Table 2

Radiological comparison between patients with closed reduction versus subjects who underwent initial closed reduction and invasive treatment.

Variable		CR n = 50 (76.9%)	CR + OR n = 3 (4.6%)	OR + FO n = 3 (4.6%)	OR + PO + FO n = 9 (13.8%)	*P*
IAI, grades, median, IQR		40º (35º–42º)	50º (43º–51.5º)	43º (40.5º–43.5º)	36 (32º–45º)	0.4
FAI, grades, mean, SD		31.9º±6.8º	25.7º ±4.5º	31.3º ±4.6º	34º ±7.5	0.3
AVN type (%)	0	35 (70)	1 (33.3)	1 (33.3)	2 (22.2)	0.009
	1	3 (6)	0 (0)	0 (0)	0 (0)	
	2	6 (12)	1 (33.3)	0 (0)	2 (22.2)	
	3	4 (8)	1 (33.3)	2 (66.7)	4 (44.4)	
	4	2 (4)	0 (0)	0 (0)	1 (11.1)	
Wiberg, grades, median, IQR		16º (8º–21º)	22º (13.5º–28º)	17º (9º–18.5º)	17º (11º–26º)	0.5
Sharp, grades, mean, SD		51.3º±3.9º	46.3º ±0.6º	48.3º ±5.5	49.8º ±5.6	0.1
CTD, mm, median, IQR		11 (7–12)	8 (7–10)	7 (7–7.5)	7 (–3 – 9)	0.04
Acetabulum type, Ogata (%)	1	2 (4)	0 (0)	0 (0)	0 (0)	<0.001
	2	18 (36)	2 (66.7)	1 (33.3)	0 (0)	
	3	27 (54)	1 (33.3)	1 (33.3)	2 (22.2)	
	4	3 (6)	0 (0)	1 (33.3)	7 (77.8)	

AVN = avascular necrosis of the proximal femoral epiphysis, CR = closed reduction, CTD = center-trochanter distance, FAI = final acetabular index, FO = femoral osteotomies, IAI = initial acetabular index, IQR = interquartile range, OR = open reduction, PO = pelvic osteotomies, SD = standard deviation.

contrast, the total prevalence of AVN was 30% in successful CR. Wang,[23] coincides with these results, indicating that in child aged 36-month-old, the risk of AVN is lower in those who undergo a successful CR, and the OR is a risk factor for the development of AVN in those aged. In comparison, he also found that the rate of AVN in children aged < 18 months was almost half that of children aged > 18 months, which implies the importance of early diagnosis in DDH. Similarly, another report in children, such as our population and those aged > 28 months, estimates a similarly

differences were observed, which provides evidence that the remodeling and development of the acetabulum could be possible even at ages from 24 to 36 months. In addition, the measurement of the CTD showed differences: the CR group showed positive values with less relative overgrowth of the greater trochanter with femoral neck valgus. In contrast, the Wiberg and the Sharp Angles did not show differences in either group, the final measurements in these assessments, were acceptable.

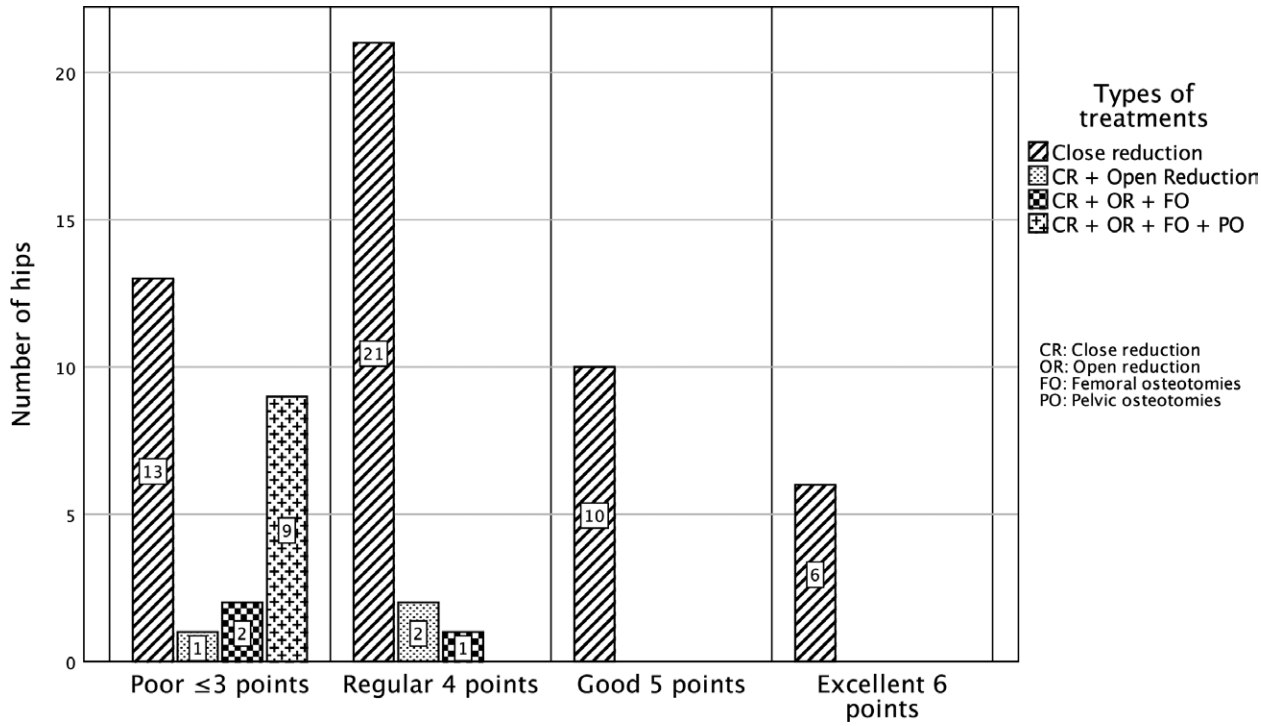

Figure 2. score and results of radiological evaluation using the Ömeroğlu classification system in hips that underwent closed reduction and in hips that required additional treatment. H (3) = 16.451, $P < .001$. H = hilgenreiner.

In this report, to evaluate the results, the Ömeroğlu[18] system was used as a reference because it considers quantitative measurements, has acceptable inter- and intra-observer reliability, and because gold standards such as the Severin scale have reported poor inter-observer reliability.[27] The radiologic results of this report, match with another report,[7] which refers satisfactory outcomes in 56.4% of the cases using Severin classification in subjects with CR efficacious. In our report, there was a predominance of unsatisfactory results (≤4 points) in the hips that had to undergo open reduction or osteotomies after failed CR; we believe that this high frequency of unsatisfactory results is due to the fact that such a system takes into account 3 modifiers and subtracts points from the final result, which is frequently found in hips with CR failure and there is a tendency for unsatisfactory results, without necessarily having repercussions on functional results. Therefore, an investigation should be carried-out to compare both aspects, and to provide long-term information on the ability of the Ömeroğlu system to predict poor function in patients with DDH in adolescence/young adulthood.

The limitations of the study were the impossibility of performing arthrography intraoperatively, the inability to observe medial contrast pool and intra or extraarticular soft tissue obstacles to reduction, which could influence the surgeon not to decide OR, FO or PO. Another limitation was the impossibility of performing pelvic tomography or resonance in CR to assess concentric reduction, since this imaging method is sensitive and specific for detecting poor reduction of the hip and detection of residual subluxation, which may not be detectable in pelvic AP. Finally, we did not include 33 hips because they did not meet the selection criteria; this loss of patients may introduce bias, and the lack of clinical information leaves a void in the analysis of the hips.

The strengths of this study include the determination of the intra-observer variability in all the carried-out measurements, which could reduce the measurement bias because they were all carried-out by a single researcher, which strengthens the internal validity of the study. In addition, a follow-up of more than 2 years was performed, and all patients were older than 5 years, which is an essential requirement to apply the Ömeroğlu classification system.

5. Conclusions

Hips that undergo surgical procedures like OR, FO, and PO, in which CR fails and that are between 24 to 36 months of age present a high frequency of unsatisfactory results in the radiological evaluation with the Ömeroğlu system. Similarly, there is a higher prevalence of AVN in hips with failed CR that also requires OR, and osteotomies treatment. Subjects treated with CR alone developed regular acetabular coverage (Ogata type 3) at 54%. The FAI in this report showed correction in all types of treatment. In subjects with effective CR, regular, good, and excellent outcomes can be projected in 57% of the cases. CR could have better results and should be used before OR and osteotomies, to diminish invasive procedures, but stricter selection criteria should be used for patients older than 24 months before implementing CR.

Author contributions

Conceptualization: Sergio Charles-Lozoya.
Data curation: Salvador Chávez-Valenzuela, Edgar Manilla-Muñoz.
Methodology: Héctor Cobos-Aguilar, Edgar Manilla-Muñoz, Miguel Leonardo De La Parra-Márquez.
Supervision: Sergio Charles-Lozoya, Héctor Eliud Arriaga-Cazares, Adrián García-Hernández.
Validation: Sergio Charles-Lozoya, Héctor Cobos-Aguilar, Adrián García-Hernández.
Writing – original draft: Sergio Charles-Lozoya, Salvador Chávez-Valenzuela.
Writing – review & editing: Sergio Charles-Lozoya, Salvador Chávez-Valenzuela, Héctor Cobos-Aguilar, Miguel Leonardo De La Parra-Márquez.

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