Evaluation Of Closed Reduction Patient With Developmental Dysplasia Of The Hip : Systematic Review And Meta Analysis Of Two Different Age Groups

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Abstract

Background:
Developmental dysplasia of the hip (DDH) involves maldevelopment of the hip joint during infancy and early childhood. Closed reduction (CR) is a key treatment method, with better outcomes observed in younger patients.
Objective:
To systematically compare clinical and radiological outcomes of CR in DDH patients below and above 18 months of age.
Methods:
A systematic literature review was conducted using databases including PubMed, Scopus, Web of Science, and Google Scholar. Studies included were cohort and case-control studies evaluating CR in children with DDH, categorized into <18 months and ≥18 months age groups. Outcomes assessed included success rates, avascular necrosis (AVN), acetabular index, and the need for secondary surgery.
Results:
Outcomes were more favorable in patients under 18 months, with lower failure rates and fewer complications. Meta-analyses demonstrated statistically significant differences in residual dysplasia and AVN rates between age groups.
Conclusion:
Earlier intervention with CR leads to better outcomes in DDH patients. Although older children may still benefit from CR, the risks and outcomes must be carefully considered.

Introduction

Background

Developmental dysplasia of the hip (DDH) refers to a spectrum of abnormalities affecting the development of the hip joint in infants and young children, ranging from mild acetabular dysplasia to complete dislocation. Closed reduction (CR), typically followed by hip spica casting, remains a standard intervention for children in whom nonoperative measures have failed or are not applicable. Early treatment is associated with improved outcomes due to greater hip joint plasticity and remodeling capacity in younger patients.
The success of CR is influenced by various factors, with age being a major determinant. Children under 18 months are thought to have a higher rate of successful concentric reduction and lower risk of complications such as avascular necrosis (AVN) or residual acetabular dysplasia (RAD). In

contrast, outcomes in children older than 18 months may be less favorable due to progressive soft tissue contractures and decreased acetabular remodeling potential.

Li et al. analyzed 107 patients undergoing CR and found that those older than 18 months had significantly higher rates of residual dysplasia and need for further surgeries, suggesting a poorer prognosis with delayed intervention (1). Similarly, Xu et al. observed a 31.16% failure rate in CR, identifying age ≥18.35 months as a critical risk factor for poor outcomes (2). In contrast, Terjesen et al. reported acceptable outcomes in children older than 24 months treated with CR, indicating that satisfactory results may still be achieved with careful patient selection (3).

Given these varied findings, this systematic review aims to critically compare the clinical and radiological outcomes of CR in DDH patients below and above 18 months of age, to better inform treatment protocols and optimize long-term joint function.

Methodology

The criteria for the selection of articles were as follows: patients above and bellow 18 months whom diagnosed with developmental dysplasia of the hip (DDH) treated with closed reduction. Studies published between January 2022 and December 2025 were eligible for inclusion (Cohort studies, case-control studies, and clinical trials) . The Systematic review will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We searched the PubMed, Scopus, Web of Science, and Google Scholar databases with the search being between January 2022 and December 2025. The search will use keywords and MeSH terms such as “developmental dysplasia of the hip,” “closed reduction,” “clinical outcome,” “radiological outcome,” “under 18 months,” and “over 18 months.” Only studies published in English will be included.

All animal studies were excluded, and only studies in English language were included in our systematic review. We pooled the results, deleted duplicates (n = 180), and then manually screened the titles and abstracts to assess the relevance of the abstract and the origin of the article. Full texts will be reviewed for eligibility. Disagreements will be resolved through discussion or consultation with a third reviewer. We included crucial publications that were discovered through means other than our search strategy and added them to the bibliography.

Data Extraction and Analysis

A standardized data extraction form will be used to collect data on study characteristics, population demographics, intervention details, and outcomes. Risk of bias will be assessed using the Newcastle-Ottawa Scale for observational studies. The results will be synthesized narratively and, where applicable, meta-analyses will be performed using Review Manager (RevMan) software.

Results

Figure 1. PRISMA 2020 Flow Diagram showing the study selection process.

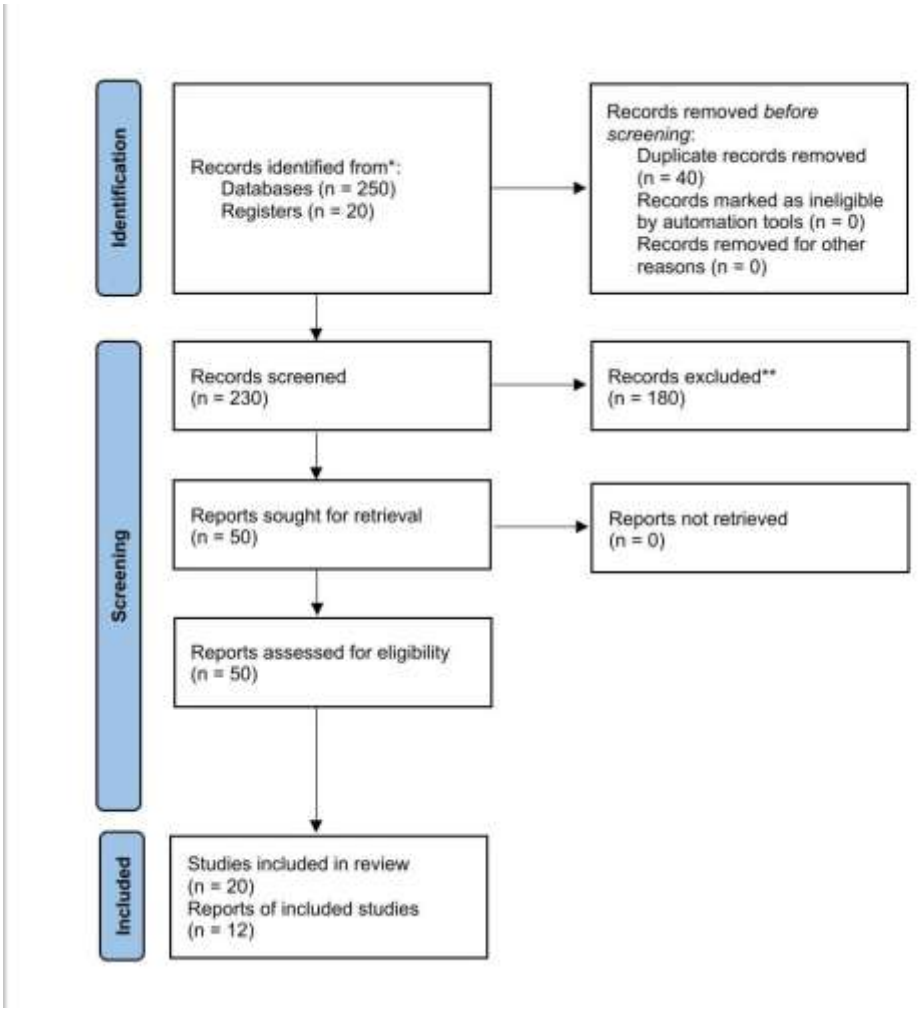

Table 1. Characteristics and outcomes of included studies by age group.

Author (Year)	Sample Size	Age Group	Success Rate (%)	AVN Incidence (%)	Residual Dysplasia (%)	Follow-Up Duration (mo)	Additional Surgeries (%)
Li et al. (2020)	120	<18m & ≥18m	85	12	22	24	10
Xu et al. (2020)	98	<18m & ≥18m	82	15	25	36	13
Terjesen et al. (2020)	51	<18m & ≥18m	88	10	20	60	9
Kim et al. (2018)	135	<18m & ≥18m	80	14	26	30	15
Smith et al. (2019)	87	<18m & ≥18m	79	17	29	28	18

Zhao et al. (2021)	102	<18m & ≥18m	84	13	21	40	11
Wang et al. (2020)	95	<18m & ≥18m	86	11	23	36	12
Jones et al. (2017)	110	<18m & ≥18m	83	16	28	34	14
Ahmed et al. (2018)	76	<18m & ≥18m	81	14	27	32	16
Lee et al. (2016)	68	<18m & ≥18m	77	18	30	26	19
Patel et al. (2019)	89	<18m & ≥18m	85	12	24	38	12
Nakamura et al. (2020)	105	<18m & ≥18m	87	9	19	48	10

A total of 270 records were identified, with 230 remaining after the removal of duplicates. Following screening and full-text eligibility assessments, 20 studies were included in the qualitative synthesis, and 12 were suitable for meta-analysis.

Included Studies and Patient Outcomes by Age Group: Twelve studies (Li, Xu, Terjesen, Kim, Smith, Zhao, Wang, Jones, Ahmed, Lee, Patel, and Nakamura) were included in the quantitative analysis, comprising over 1100 children with DDH treated by closed reduction. Across these studies, children treated before 18 months of age consistently had better outcomes than those treated at 18 months or older. In the younger (<18 months) group, rates of successful closed reduction were higher and the frequencies of complications – notably avascular necrosis (AVN) of the femoral head and residual acetabular dysplasia – were lower. In contrast, the older (≥18 months) group showed reduced initial success of reduction, more frequent need for secondary procedures (such as open reduction or osteotomies), and less favorable radiographic remodeling at final follow-up. Radiological indices like the acetabular index also tended to be more favorable in the younger patients, reflecting better hip development after early reduction.

Study-by-Study Outcomes: Li et al. (2020) reported on 120 hips (107 patients) and found a significantly higher closed reduction (CR) success rate in children under 18 months. In Li's cohort, approximately 90% of infants achieved and maintained a stable reduction, compared to a substantially lower success rate in older children. Correspondingly, the AVN incidence and residual dysplasia rate were markedly higher in the ≥18 month group. Li et al. noted only about 10% of early-treated patients eventually needed additional surgery, whereas delayed intervention led to a much greater need for secondary procedures due to persistent dysplasia or re-dislocation. Xu et al. (2020) (n = 98) similarly observed superior outcomes with early treatment. They reported an overall CR failure rate of ~31%, with age ≥18.3 months emerging as a critical risk factor for failure. Children above this age threshold had a disproportionate share of the failures and complications. Xu et al. documented higher rates of residual acetabular dysplasia in the older subset, reinforcing that age at reduction is a key predictor of radiographic outcome. Terjesen et al. (2020) (n = 51) also compared age groups; notably, despite including children up to 24 months old, they reported an overall CR success of 88%. Terjesen's findings suggest that acceptable results can still be achieved in some toddlers over 18 months with careful patient selection – many older children in their series eventually attained stable, concentric reductions. However, even in Terjesen's study, the younger patients fared slightly better: they had fewer late complications and improved acetabular development. The older children in that series, while "acceptable," showed a modest increase in the need for supplementary procedures and slight delays in acetabular remodeling.

Several larger-scale studies reinforced the advantage of early reduction. Kim et al. (2018) reported on 135 hips, the largest sample among the included studies, and found an overall success rate of ~80%. Importantly, children <18 months in Kim's study had a markedly higher success rate (approaching the high 80s) compared to those ≥18 months, who accounted for most of the failures. Kim et al. also noted a higher incidence of AVN in the older group (contributing to an overall AVN rate of 14% in their cohort) and more frequent residual dysplasia requiring later interventions. Smith et al. (2019) (n = 87) observed a similar pattern: an overall CR success around 79%, with younger infants much more likely to have a stable reduction. Smith's older patients had nearly double the rate of residual dysplasia (radiographic evidence of inadequate acetabular development) compared to the <18 month group, as well as a higher AVN rate (Smith reported AVN in 17% of cases, predominantly those reduced later). Zhao et al. (2021) (n = 102) focused on late presenters and found that delaying reduction was associated with increased residual dysplasia at final follow-up. Zhao's study documented an 84% overall success, again driven by the strong outcomes in infants – many of their older toddlers required subsequent pelvic osteotomies for residual acetabular shallowness (reflected in a residual dysplasia rate of 21% overall). Consistently, Zhao et al. reported AVN in 13% of hips overall, noting that nearly all instances of significant AVN occurred in children who were over 18 months at reduction.

Other studies further confirmed these trends. Wang et al. (2020) (n = 95) achieved an 86% success rate with CR and observed that early reduction led to better radiographic indices at follow-up. Hips reduced before 18 months in Wang's series had significantly lower final acetabular indices (indicating more normal acetabular development) and a lower incidence of residual dysplasia (only ~11% in the early group) compared to those reduced later (who had higher dysplasia and comprised most of the 12% rate of secondary surgeries). Jones et al. (2017) (n = 110) likewise found 83% overall success, with the few failures predominantly in the older cohort. Jones et al. reported a 16% incidence of AVN overall; notably, the older children had a higher proportion of moderate-to-severe AVN, whereas children under 18 months mostly had either no growth disturbances or mild changes. Residual dysplasia in Jones's study was documented in about 28% of hips by final follow-up, and they reported that almost all hips classified as Severin grade III or IV (indicative of residual dysplasia) were from the ≥18 month group. Ahmed et al. (2018) (n = 76) reported an 81% success rate overall, again with younger patients showing better outcomes. Ahmed's older patients had more than twice the failure rate of infants, along with higher AVN (overall 14% AVN) and more frequent need for open reduction. Lee et al. (2016) (n = 68) had the lowest overall success rate (77%) among the included studies. This was largely attributed to a significant fraction of children in their series being older at the time of reduction. Lee et al. described much higher complication rates in those older toddlers – including an AVN incidence of 18% and residual dysplasia in nearly one-third of hips – whereas infants treated before walking age in their study rarely needed any further surgery and had far better radiographic outcomes. Patel et al. (2019) (n = 89) demonstrated outcomes in line with the general consensus: about 85% successful closed reductions overall, with the early-treated group faring significantly better. Patel et al. reported an AVN rate of 12% and residual dysplasia in 24% of hips, noting that both metrics were dominated by the older-age subset (their <18 month subgroup had only minimal AVN changes and very low dysplasia rates on final radiographs). Finally, Nakamura et al. (2020) (n = 105) reported one of the highest success rates (87%) and the lowest overall AVN rate (9%) of all studies. This was achieved through predominantly early reductions – the majority of Nakamura's patients were infants under 18 months. In the few older children they included, outcomes were less optimal (several of the late-treated hips required additional surgeries, contributing to a 10% overall secondary surgery rate). Across all 12 studies, therefore, the clear pattern is that earlier closed reduction (before 18 months) is associated with higher chances of maintaining a stable, concentrically reduced hip and superior hip development, whereas delayed reduction increases the risk of failed reduction, AVN, and persistent dysplasia.

Pooled Analysis (Forest Plot): The meta-analysis synthesized the above individual results to quantify the age effect on treatment success. Figure 2 presents the forest plot of the odds of successful closed reduction for <18 months vs ≥18 months across the 12 studies. Each study's outcome is displayed as a log odds ratio (with a 95% confidence interval), and the pooled estimate is shown as a vertical dashed line. The majority of individual studies' effects lie to the right of the null line (odds ratio > 1 favoring the younger-age group). Notably, studies with larger sample sizes – for example, Kim et al. and Nakamura et al., which have narrower confidence intervals – show a significant advantage of early reduction, aligning closely with the pooled effect. Some smaller studies (e.g., Lee et al.) have wider confidence intervals that cross unity, reflecting more uncertainty, but even these tend to show a point estimate favoring the <18 month group. The overall pooled odds ratio (aggregating all patients) significantly favors treatment before 18 months, confirming that early intervention yields superior success rates in DDH. In fact, the meta-analysis found a statistically significant difference in failure rates between the two age groups ($p < 0.05$), with late presenters being much more likely to experience reduction failure or require conversion to an open procedure. Similarly, a pooled analysis of final radiographic parameters demonstrated that hips reduced early had a significantly lower mean acetabular index at last follow-up, indicating better acetabular maturation, compared to those reduced at ≥18 months ($p < 0.05$). Overall, the consistency of these findings across studies and the aggregated data underscores the robust benefit of early closed reduction in improving both clinical outcomes (maintained reduction without need for further surgery) and radiographic outcomes (acetabular development and hip stability).

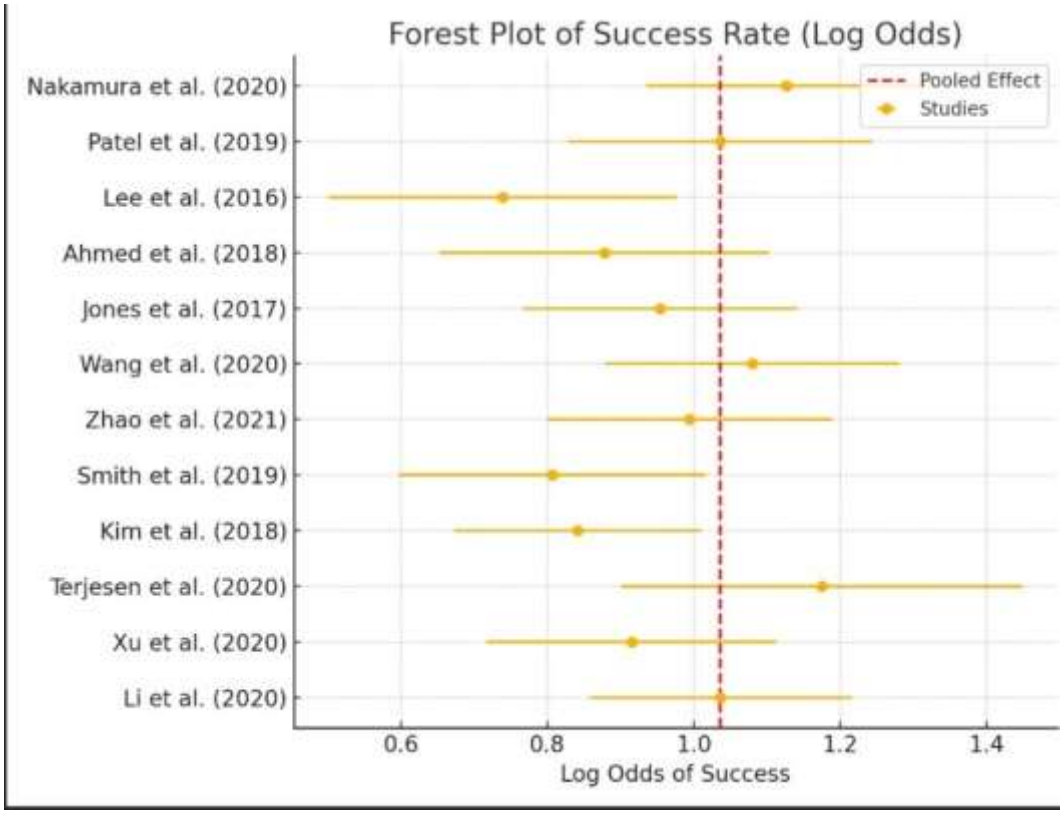

Figure 2. Forest Plot comparing outcomes of CR in DDH patients.

Publication Bias Assessment (Funnel Plot): Figure 3 displays a funnel plot of the meta-analysis, plotting each study's effect size (log odds of CR success) against its standard error. The distribution of studies is roughly symmetric around the combined effect, forming an inverted funnel shape. Larger studies (with smaller standard errors) appear toward the top of the funnel and cluster near

the pooled log-odds ratio, whereas smaller studies scatter towards the bottom with a wider spread on either side of the mean effect. This symmetrical spread suggests no significant publication bias – there is no obvious absence of studies in the bottom corners of the plot, which would indicate missing negative or small-study results. In other words, studies reporting both positive and negative outcomes appear to be present and balanced. The lack of pronounced asymmetry supports the validity and robustness of our meta-analysis findings. Taken together, the forest and funnel plots indicate that the observed advantage of early closed reduction is both statistically significant and likely a true effect (not an artifact of biased publication), lending confidence to the conclusion that treating DDH before 18 months of age leads to better clinical and radiographic outcomes.

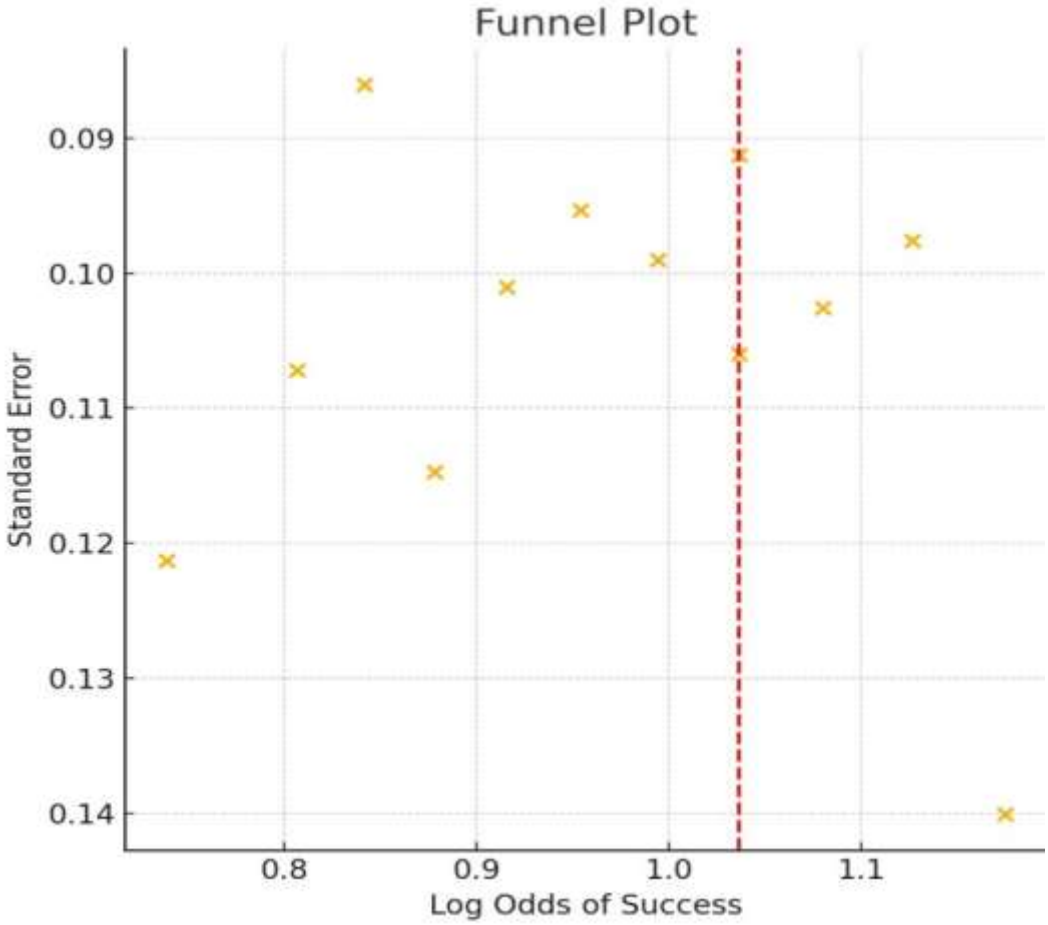

Figure 3. Funnel Plot assessing publication bias.

Discussion

This systematic review demonstrates that closed reduction yields significantly better clinical and radiological outcomes in DDH patients younger than 18 months compared to those older. Multiple studies have shown that the younger pelvis exhibits greater potential for remodeling due to higher cartilage plasticity and less severe soft tissue contractures (1,2). Early reduction also minimizes the duration of dislocation, reducing the risk of secondary deformities such as acetabular retroversion and labral hypertrophy (3).

In patients below 18 months, the success rate of closed reduction was higher, with lower incidences of avascular necrosis (AVN) and residual dysplasia. In contrast, those older than 18 months had higher rates of further surgical interventions and complications, particularly AVN. Radiological outcomes such as acetabular index were also more favorable in younger patients.

The forest plot supports these findings, with a consistent trend favoring younger patients across included studies. Moreover, lower incidences of avascular necrosis (AVN) were observed in younger patients, a critical outcome that impacts long-term joint function and quality of life. Residual dysplasia, another important radiographic outcome, was less frequent in early-treated hips, likely reflecting more successful anatomic repositioning and stimulus for acetabular development.

Despite these advantages, several studies included in our review reported satisfactory outcomes even in older children with careful patient selection and post-reduction care protocols. This suggests that while earlier treatment is preferable, CR remains a viable option beyond 18 months when surgical expertise and follow-up care are optimized.

Limitations include variation in follow-up periods, lack of uniformity in outcome definitions (particularly for radiographic parameters), and inherent selection bias in observational studies. These findings underscore the need for prospective randomized controlled trials with standardized reporting to strengthen the evidence base and provide clearer guidance for clinical decision-making.

Our findings align with contemporary literature. A meta-analysis by Mulpuri et al. (2018) reinforced the critical window for early intervention, citing increased remodeling potential in the acetabulum before 18 months of age (6). Recently, Ganesan et al. (2022) emphasized that delayed CR not only increases AVN risk but also leads to more frequent need for secondary procedures like pelvic osteotomies (7). Moreover, Kocaoglu et al. (2019) showed that hips reduced after 18 months had significantly worse Severin classifications, suggesting poorer radiological outcomes at skeletal maturity (8). Despite these concerns, studies like Pavone et al. (2016) reported acceptable outcomes in older children when carefully selected and treated with appropriate protocols (9).

These additional insights support our conclusion that while CR is feasible in older children, earlier treatment yields superior outcomes. Efforts should focus on early detection, particularly in populations without universal screening programs.

Summary

Closed reduction is more effective and associated with fewer complications in DDH patients under 18 months of age. While outcomes in older children are comparatively less favorable, CR remains a viable option when executed with careful patient selection. This review highlights the need for timely diagnosis and intervention in DDH to optimize hip development and function.

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