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Hip Abduction in Spica Casting and Osteonecrosis After Closed Reduction for Developmental Dysplasia of the Hip

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Abstract

Purpose Hip position after closed reduction must balance stability against vascular compromise, but the abduction angle associated with osteonecrosis remains uncertain.

Methods PubMed/MEDLINE and PubMed Central were searched from inception through 13 September 2026. Eligible studies included children treated for idiopathic developmental dysplasia or dislocation of the hip and reported a measured or categorized post-reduction abduction angle with osteonecrosis or reduction-stability outcomes. Two-stage screening, cohort-overlap assessment, and structured risk-of-bias appraisal were performed. Because exposure definitions, age strata, outcome classifications, and effect measures were incompatible, quantitative pooling was not undertaken.

Results Eight clinically relevant cohorts were retained for the principal synthesis. A closed-reduction cohort of 82 hips found no overall linear association, but among children aged 6 months or younger osteonecrosis occurred in 9 of 15 hips cast at 50 degrees or more versus 0 of 8 below 50 degrees. A separate 89-hip cohort reported a strong association above 54 degrees, whereas a 59-hip late-detected cohort found no association across a substantially higher mean angle of 70.2 degrees. A protocol-era comparison of 86 children found similar osteonecrosis rates at approximately 60 and 45 degrees (19% versus 16%). Recent mixed-reduction cohorts provided conflicting adjusted findings. Redislocation was infrequently and inconsistently reported.

Conclusion Available observational evidence does not establish a universal safe abduction threshold. The association may be modified by age, reduction difficulty, perfusion, and treatment era. Angles at or above 50 to 60 degrees warrant particular caution in younger infants, but cast position should be individualized to achieve stable concentric reduction without forceful abduction.

Keywords developmental dysplasia of the hip; closed reduction; hip spica; abduction; osteonecrosis; avascular necrosis

Introduction

Closed reduction followed by hip-spica immobilization remains an established treatment for developmental dysplasia of the hip (DDH) when harness or brace treatment fails or diagnosis occurs after early infancy. Osteonecrosis of the femoral head is among its most consequential complications because proximal femoral growth disturbance can impair acetabular development, alter joint mechanics, and increase later reconstructive requirements.

The position of immobilization is clinically modifiable. Increasing abduction may improve containment and resist redislocation, but excessive abduction can raise soft-tissue tension and compromise femoral-head perfusion. The classic safe-zone concept captures this balance, yet published thresholds range from approximately 45 to more than 70 degrees and are often applied without accounting for age or reduction severity.

The purpose of this systematic review was to evaluate hip abduction as a quantitative or categorized exposure after reduction for DDH, determine whether its association with osteonecrosis differs by age, and examine the competing outcome of loss of reduction. The hypothesis was that the evidence would support an age-dependent rather than universal threshold.

Methods

Design and reporting

This review was conducted as a systematic review with structured evidence synthesis and reported according to PRISMA 2020 principles. No patient-level data were used. The analytic plan specified separate consideration of closed-reduction-only and mixed closed/open cohorts and prohibited pooling of clinically incompatible angle definitions or osteonecrosis endpoints.

Search strategy

PubMed/MEDLINE and PubMed Central were searched from inception through 13 September 2026. Search concepts combined developmental dysplasia or developmental dislocation of the hip, closed reduction or reduction, spica or immobilization, abduction angle or hip position, and avascular necrosis or osteonecrosis. Reference lists of eligible articles and contemporary reviews were screened. The reproducible PubMed string was: (developmental dysplasia hip OR developmental dislocation hip) AND (abduction angle OR spica position) AND (avascular necrosis OR osteonecrosis).

Eligibility criteria

Cohort studies were eligible when children with idiopathic DDH underwent reduction and spica immobilization, post-reduction hip abduction was measured or categorized, and osteonecrosis or loss of reduction was reported. Mixed closed/open cohorts were retained only as secondary evidence when treatment groups could not be completely separated. Measurement-only, biomechanical, adult, syndromic, teratologic, and non-outcome studies were excluded.

Data extraction and appraisal

Extracted items included study design, treatment era, age, number of hips, reduction method, angle measurement modality, exposure scale or threshold, osteonecrosis definition, follow-up, redislocation, and adjusted or unadjusted associations. Risk of bias was evaluated using QUIPS domains. Confounding by reduction stability, age, dislocation severity, prior traction, ossific nucleus, and treatment era was considered critical.

Synthesis

Adjusted estimates were prioritized. Meta-analysis was prespecified only when at least three independent cohorts used compatible exposure contrasts and outcome definitions. That condition was not met. Findings were therefore organized by age, angle threshold, and reduction method, with exact study estimates presented where available.

Results

Study selection

The electronic search identified 66 records. After title and abstract screening, 12 reports underwent detailed eligibility assessment; eight clinically relevant cohorts were included in the principal synthesis. Excluded full texts were measurement-only or biomechanical reports, open-reduction-only cohorts, or reports without an angle-outcome association. The included evidence was entirely observational and spanned markedly different treatment eras.

Table 1 Principal studies of abduction angle and osteonecrosis

Study	Population	Angle exposure	Osteonecrosis finding	Interpretive limitation
Castaneda et al. 2016	82 hips; mean age 10 mo; closed reduction	Continuous and ≥ 50 deg	Overall null; age ≤ 6 mo: 9/15 vs 0/8 at ≥ 50 vs < 50 deg	Post hoc age subgroup; 1986-2009 era
Li et al. 2019	59 hips; age 6-28 mo; closed reduction	MRI mean 70.2 deg; range 53-85	8/59 AVN; no association with angle ($p=0.97$)	Short mean follow-up; older cohort

Khoshhal et al. 2013	86 children; closed or medial open reduction	Protocol cohorts near 60 vs 45 deg	AVN 19% vs 16% (p=0.78); one redislocation at 45 deg	Mixed reduction methods; nonrandom era comparison
Aslani et al. 2023	89 hips; age 6-24 mo; closed reduction	ROC cutoff >54 deg	Adjusted OR 38.44 (95% CI 4.14-293.74)	Internal inconsistency in reported group means; wide CI
Yoo et al. 2021	58 hips; age 3-18 mo; closed reduction	Study-defined excessive abduction	Univariate OR 4.65 (95% CI 1.20-18.06)	One-year AVN assessment; MRI-perfusion pathway
Wang et al. 2024	169 hips; 102 closed, 67 open	>=60 deg	Significant adjusted association; 25/76 exposed hips developed AVN	Mixed reductions and inverse coding complicate OR direction
Recent MRI cohort 2025	94 hips; closed and open reduction	Continuous abduction	No adjusted association with any or severe AVN	Mixed treatments; perfusion-focused study
Dunker 1984	388 dislocations; varied conservative pathways	>45 deg with poor reduction	Higher AVN with mechanical risk constellation	Historical protocols; non-isolated effect

Osteonecrosis by age and threshold

The strongest age-specific signal came from Castaneda and colleagues. Although the continuous angle and the ≥ 50 -degree comparison were null in the full cohort, every osteonecrosis event in the ≤ 6 -month subgroup occurred in the higher-abduction category. This interaction is clinically provocative but statistically fragile because it arose from 23 hips and included a zero-event comparator.

The 2023 cohort reported discrimination at 54 degrees and a very large adjusted odds ratio. Its tables, however, report mean angles in the osteonecrosis and non-osteonecrosis groups in an order that conflicts with the stated direction of effect. The threshold estimate is therefore best interpreted as supportive but requiring source-data verification.

In contrast, the late-detected cohort with a mean post-reduction angle above 70 degrees observed no angle association. This does not establish safety at high angles: older age, different vascular tolerance, selection of stable reductions, and short follow-up can all attenuate or obscure the relationship.

Reduction stability

Loss of reduction was too inconsistently reported for formal synthesis. The protocol-era comparison observed one redislocation in the lower-abduction group and none in the higher-abduction group, but the absolute numbers were insufficient to estimate a clinically reliable tradeoff. Several studies selected angle in response to intraoperative stability, producing confounding by indication.

Risk of bias and certainty

All included studies had at least moderate risk of bias. Confounding was the dominant concern: a hip requiring more abduction may have been more severe or less stable before casting. Outcome classification and follow-up varied, bilateral hips were often treated as independent, and threshold analyses were commonly data derived. Overall certainty was very low for a universal threshold and low for an age-dependent association in younger infants.

Discussion

This review does not support a single safe abduction angle applicable to every child undergoing closed reduction for DDH. The most defensible interpretation is that risk depends on the interaction between age, reduction force, underlying severity, and perfusion. Evidence suggesting harm at approximately 50 to 60 degrees is concentrated in selected young or heterogeneous cohorts, while older late-detected children have shown null associations even at larger angles.

These apparently conflicting observations are clinically coherent. Chronological age may alter vascular susceptibility and soft-tissue stiffness; the measured bony-axis angle may not represent capsular tension uniformly across patients; and surgeons increase abduction when a reduction is unstable. Consequently, high abduction can be both a causal mechanical exposure and a marker of a difficult hip.

Clinical implications

The evidence favors a physiologic rule rather than a universal number: obtain a concentric, stable reduction within the individual safe zone and avoid additional abduction once stability has been achieved. In infants 6 months or younger, angles of 50 degrees or more should prompt particular scrutiny of stability, adductor tension, and femoral-head perfusion. In older children, a high measured angle should not be declared safe merely because some cohorts were null.

Post-reduction MRI or ultrasonography can confirm reduction and may identify perfusion abnormalities, but current perfusion evidence is itself heterogeneous. If stability requires forceful abduction, the operative decision should incorporate arthrographic obstacles, adductor release, and whether open reduction offers a less ischemic path to

concentric containment.

Limitations

The review was limited by observational designs, inconsistent angle definitions, variable osteonecrosis classifications, sparse adjusted estimates, and incomplete reporting of redislocation. The search was concentrated in PubMed-indexed literature and citation chaining; Embase and Scopus were not independently queried. Several potentially relevant mixed-treatment cohorts could not yield closed-reduction-specific estimates. These limitations precluded meta-analysis and make any numeric threshold provisional.

Conclusion

Post-reduction hip abduction is plausibly associated with osteonecrosis after treatment of DDH, but available evidence does not define a universal safe angle. The signal is most concerning at or above approximately 50 to 60 degrees in younger infants, while findings in older children are inconsistent. Prospective multicenter studies should record standardized three-dimensional angle measurements, perfusion, intraoperative stability, and both osteonecrosis and redislocation, with prespecified age interactions.

Declarations

Conflict of interest: none declared. Funding: none. Ethics approval: not required for a review of published data. Data availability: all analyzed information is contained in the cited publications.

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