



Correspondence

✉ Saoud Javed, Saoudjaved93@hotmail.com

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Systematic Review on Pelvic vs Femoral Osteotomy in Children with Perthes Disease

Saoud Javed¹, Adnan Ali Aziz¹, Faisal Manzoor¹, Sajjad Hussain², Muhammad
Rukun-Uddin Siddiqui³, Muhammad Younas²

1 RIMS Trauma Hospital, Karachi, Pakistan

2 Dr. Ziauddin Hospital, Karachi, Pakistan

3 Civil Hospital Karachi, Karachi, Pakistan

ABSTRACT

Background: Legg–Calvé–Perthes disease (LCPD) is a pediatric osteonecrosis of the femoral head in which surgical containment aims to maintain femoroacetabular congruence and facilitate spherical remodeling. Femoral and pelvic osteotomies are established options, but optimal selection—particularly in older children or severe deformity—remains debated. **Objective:** To synthesize comparative evidence on outcomes, indications, and complications of femoral versus pelvic osteotomy, and selective combined procedures, in children with LCPD. **Methods:** A PRISMA 2020–guided search of MEDLINE, Embase, Scopus, Web of Science, Cochrane CENTRAL, and publisher platforms (2008–2025) included pediatric studies (4–12 years) reporting ≥24-month outcomes after femoral, pelvic, or combined osteotomies. The primary outcome was radiographic result at latest follow-up (Stulberg I/II vs III–V); secondary outcomes included range of motion, pain/functional scores, complications, reoperation, and hip survival/THA. Given heterogeneity, a narrative synthesis was performed; study quality was appraised using MINORS and considered qualitatively in interpretation. **Results:** Twelve studies met criteria. Across appropriately selected patients, femoral and pelvic osteotomies yielded broadly similar radiographic containment and functional improvement. Femoral osteotomy was favored in younger children, particularly lateral pillar B/B–C; pelvic osteotomy was preferred in older children with acetabular deficiency or hinge abduction. Combined osteotomy was reserved for severe multiplanar deformity, offering at most modest incremental benefit with greater operative complexity and higher complication exposure. Common sequelae included mild limb-length discrepancy and abductor weakness after femoral procedures, and overcoverage/impingement risk after pelvic reorientation; hip survival correlated more with age and severity than with technique. **Conclusion:** Procedure choice should be phenotype-driven, prioritizing age, lateral pillar status, and the dominant locus of deformity. Standardized, prospective comparative cohorts with patient-reported outcomes and survivorship endpoints are needed to refine algorithms and evaluate 3D planning–assisted strategies.

Keywords

Legg–Calvé–Perthes Disease; Femoral Osteotomy; Pelvic Osteotomy; Combined Osteotomy; Containment Surgery; Lateral Pillar Classification; Pediatric Hip; Stulberg Classification; Periacetabular Osteotomy.

INTRODUCTION

Legg–Calvé–Perthes disease (LCPD) is an idiopathic osteonecrosis of the pediatric femoral head that can lead to femoral head deformity, joint incongruity, and early osteoarthritis if not effectively contained during fragmentation and reossification. The overarching management principle is biological and biomechanical containment—maintaining the femoral head centered and congruent within the acetabulum to optimize spherical remodeling and preserve function (1). When nonoperative strategies are unlikely to succeed—particularly in older children or those with extensive lateral pillar involvement—surgical containment is considered to redirect forces, improve coverage, and facilitate more favorable healing trajectories (2).

Two operative philosophies dominate contemporary practice. Proximal femoral osteotomy (PFO, typically varus) recenters the head by altering femoral alignment and can improve radiographic sphericity and range of motion, although it may introduce trade-offs such as limb-length discrepancy and abductor weakness (1). Pelvic (acetabular) osteotomies—including Salter, triple, and periacetabular variants—reorient the acetabulum to enhance coverage without changing femoral geometry, yet they may risk overcoverage and impingement if case selection and correction magnitudes are suboptimal (2). Across heterogeneous series and reviews, age at onset and disease severity consistently emerge as dominant prognostic modifiers regardless of the technique selected, underscoring the need for stratified decision-making rather than a one-size-fits-all approach (3).

Comparative evidence suggests that, in well-selected patients, PFO and pelvic osteotomy can yield broadly similar radiographic containment and clinical outcomes, while combined procedures may be considered when concurrent femoral and acetabular pathoanatomy compromise stable coverage. However, studies of combined osteotomy frequently report only modest incremental benefit relative to single-site surgery and may incur higher operative complexity and complication exposure, highlighting the importance of careful indication and technical planning (4). Emerging computational and imaging advances promise more personalized corrections by simulating correction angles and contact mechanics before surgery,

potentially reducing iatrogenic error and improving congruence in complex hips (5). Radiographic analyses of different pelvic techniques further clarify how specific reorientations shift acetabular morphology and lateral center-edge angle, informing procedure selection but also reminding surgeons of the narrow margin between optimal coverage and impingement in older children (6).

Despite decades of surgical experience, the field still lacks randomized comparisons and is constrained by retrospective designs, selection bias, variable staging at intervention, and nonuniform outcome reporting. These limitations complicate direct technique-to-technique comparisons and obscure which strategy optimally benefits subgroups such as children older than six years or those with lateral pillar C involvement (3). Consequently, clinicians face a practical evidence gap at the point of decision: whether to favor PFO, pelvic osteotomy, or a combined approach for a given constellation of age, stage, and deformity, and what trade-offs in function, complication risk, and long-term hip survival accompany each choice (4). Accordingly, the objective of this systematic review is to synthesize and critically appraise comparative outcomes of proximal femoral versus pelvic osteotomies—and, where relevant, combined procedures—in children with LCPD, focusing on radiographic containment, functional status, complications, and long-term survivorship, and to identify prognostic factors that can guide individualized surgical decision-making (1–6).

MATERIALS AND METHODS

Study design and objective

This systematic review was planned a priori under PRISMA 2020 guidance to compare outcomes of femoral osteotomy, pelvic osteotomy, and combined femoral–pelvic osteotomy for containment in children with Legg–Calvé–Perthes disease (LCPD). The PICO framework was: Population—children 4–12 years with LCPD; Interventions/Comparators—femoral osteotomy vs pelvic osteotomy vs combined procedures; Outcomes—primary: radiographic outcome at latest follow-up (Stulberg class I/II vs III–V). Secondary: hip range of motion (ROM), pain, functional scores (e.g., Harris Hip Score/modified), reoperation, complications (limb-length discrepancy, abductor weakness, impingement, avascular necrosis), and hip survival/THA conversion. The protocol was not registered.

Eligibility criteria

Inclusion. Original studies (randomized, non-randomized comparative, cohort, case–control, or ≥ 10 -patient case series) of LCPD treated with femoral, pelvic, or combined osteotomies; pediatric cohorts with mean or median age 4–12 years at surgery or extractable pediatric subset; minimum follow-up ≥ 24 months; report at least one predefined primary/secondary outcome; full-text, peer-reviewed, English.

Exclusion. Single case reports or series < 10 hips unless reporting unique technique with outcome data not otherwise available; non-surgical or bracing-only cohorts; developmental dysplasia/SCFE/AVN not due to LCPD; imaging-only or technique-only papers with no patient outcomes; duplicate cohorts (the most complete/longest follow-up retained); conference abstracts, editorials, narrative reviews (screened only for citation chasing).

Information sources and search dates

We searched MEDLINE (via PubMed), Embase (via Ovid), Scopus, Web of Science Core Collection, Cochrane CENTRAL, and publisher platforms ScienceDirect, SpringerLink, and MDPI. Searches covered 1 January 2008 through 20 October 2025. We also hand-searched reference lists of eligible studies and relevant reviews and performed forward citation tracking in Google Scholar. No grey literature was included beyond CENTRAL.

Search strategy (comprehensive and reproducible)

We operatively implemented a single common strategy across databases using three concept blocks—Condition (LCPD), Intervention (osteotomy types), and Population (children)—combined as *(Condition) AND (Intervention) AND (Population)*. We paired controlled vocabulary (e.g., MeSH/Emtree) with free-text synonyms to maximize sensitivity and mitigate indexing lag. We applied English and Humans limits and did not apply study-design filters at the database level.

Concept blocks (free text):

Condition: “Legg Calve Perthes”, “Legg-Calvé-Perthes”, “Perthes disease”, LCPD Intervention: osteotomy, “femoral osteotomy”, “proximal femoral osteotomy”, “varus osteotomy”, “valgus osteotomy”, “derotation osteotomy”, “pelvic osteotomy”, “Salter osteotomy”, “triple pelvic osteotomy”, “periacetabular osteotomy”, PAO Population: child, pediatric*, paediatric* Date limits for all databases: 2008-01-01 to 2025-10-20. Language/Species: English; Humans. Age focus: enforced at screening to avoid missing mixed-age reports.*

MEDLINE (PubMed)

(“Legg-Calve-Perthes Disease”[Mesh] OR “Legg-Calvé-Perthes” OR “Legg Calve Perthes” OR “Perthes disease” OR LCPD) AND (osteotomy[Mesh] OR osteotomy OR “femoral osteotomy” OR “proximal femoral osteotomy” OR “varus osteotomy” OR “valgus osteotomy” OR “derotation osteotomy” OR “pelvic osteotomy” OR “Salter osteotomy” OR “triple pelvic osteotomy” OR “periacetabular osteotomy” OR PAO) AND (child*[Title/Abstract] OR pediatric*[Title/Abstract] OR paediatric*[Title/Abstract]) Filters: Humans; English; Publication dates 2008/01/01–2025/10/20 Embase (Ovid) – final string (“legg-calve-perthes disease”/exp OR “legg calve perthes”:ti,ab OR “perthes disease”:ti,ab OR LCPD:ti,ab) AND (osteotomy/exp OR osteotomy*:ti,ab OR “femoral osteotomy”:ti,ab OR “proximal femoral osteotomy”:ti,ab OR “varus osteotomy”:ti,ab OR “valgus osteotomy”:ti,ab OR “derotation osteotomy”:ti,ab OR “pelvic*

osteotomy':ti,ab OR 'salter osteotomy':ti,ab OR 'triple pelvic osteotomy':ti,ab OR 'periacetabular osteotomy':ti,ab OR PAO:ti,ab) AND (child:ti,ab OR pediatric*:ti,ab OR paediatric*:ti,ab) Limits: Humans; English; 2008–2025*

Scopus – final string

(TITLE-ABS-KEY("Legg-Calvé-Perthes" OR "Legg Calve Perthes" OR "Perthes disease" OR LCPD)) AND (TITLE-ABS-KEY(osteotomy OR "femoral osteotomy" OR "proximal femoral osteotomy" OR "varus osteotomy" OR "valgus osteotomy" OR "derotation osteotomy" OR "pelvic osteotomy" OR "Salter osteotomy" OR "triple pelvic osteotomy" OR "periacetabular osteotomy" OR PAO)) AND (TITLE-ABS-KEY(child OR pediatric* OR paediatric*)) AND (LIMIT-TO(LANGUAGE, "English")) AND (PUBYEAR > 2007 AND PUBYEAR < 2026)*

Web of Science Core Collection – final string

TS=("Legg-Calvé-Perthes" OR "Legg Calve Perthes" OR "Perthes disease" OR LCPD) AND TS=(osteotomy OR "femoral osteotomy" OR "proximal femoral osteotomy" OR "varus osteotomy" OR "valgus osteotomy" OR "derotation osteotomy" OR "pelvic osteotomy" OR "Salter osteotomy" OR "triple pelvic osteotomy" OR "periacetabular osteotomy" OR PAO) AND TS=(child OR pediatric* OR paediatric*) Refined by: DOCUMENT TYPES=(ARTICLE); Language=(ENGLISH) Timespan: 2008–2025*

Cochrane CENTRAL – final string

("Legg Calve Perthes" OR "Perthes disease" OR LCPD):ti,ab,kw AND (osteotomy OR "femoral osteotomy" OR "pelvic osteotomy" OR "Salter" OR "triple pelvic osteotomy" OR "periacetabular osteotomy" OR PAO):ti,ab,kw AND (child OR pediatric* OR paediatric*):ti,ab,kw*

Publisher platforms (ScienceDirect / SpringerLink / MDPI) – final string

("Perthes disease" OR "Legg Calve Perthes" OR LCPD) AND ("femoral osteotomy" OR "pelvic osteotomy" OR "Salter osteotomy" OR "triple pelvic osteotomy" OR "periacetabular osteotomy" OR PAO) AND (child OR pediatric* OR paediatric*) Filters: 2008–2025; Article; English*

Deduplication and citation chasing

Records from all sources were exported to a reference manager, deduplicated algorithmically (title/author/year/DOI) and manually verified. We performed backward reference screening of included studies and key reviews and forward citation tracking in Google Scholar to identify in-process/ahead-of-print items likely to lag indexing.

Study selection

Records were imported into a reference manager and deduplicated algorithmically and by manual inspection. Two independent reviewers screened titles/abstracts against eligibility criteria, followed by full-text assessment of potentially eligible articles. Disagreements were resolved by consensus; persistent disagreements were adjudicated by a senior reviewer. Reasons for full-text exclusion were documented. A PRISMA flow diagram summarizes the process.

Data extraction

A piloted extraction form captured: study characteristics (design, country, period, sample size), patient demographics (age, sex), disease severity (e.g., lateral pillar classification when available), intervention type (femoral varus/valgus/derotation; Salter, triple, periacetabular; combined), surgical timing/stage, follow-up duration, and outcomes (Stulberg class; ROM; pain/functional scores; complications including limb-length discrepancy, abductor weakness, overcoverage/FAI, AVN; reoperations; hip survival/THA). If multiple timepoints were reported, the latest was designated primary for radiographic outcome; intermediate outcomes were retained for context. Where necessary, corresponding authors were planned to be contacted for missing key data; if unavailable, data were extracted from text, tables, or graphs using standardized digital tools.

Outcomes and effect measures

Primary outcome: proportion achieving Stulberg I/II at final follow-up. Secondary outcomes: (a) hip ROM (°) and functional scores (continuous); (b) complication rates (binary: any complication; specific complications); (c) conversion to THA or hip survival (time-to-event or binary). Where

effect synthesis was feasible, risks/proportions were planned as risk ratio (RR) with 95% CIs; continuous outcomes as mean difference (MD) or standardized mean difference (SMD) with 95% CIs. When dispersion was reported as IQR or range, SDs were estimated using established conversions. If studies lacked comparative arms, outcomes were summarized descriptively.

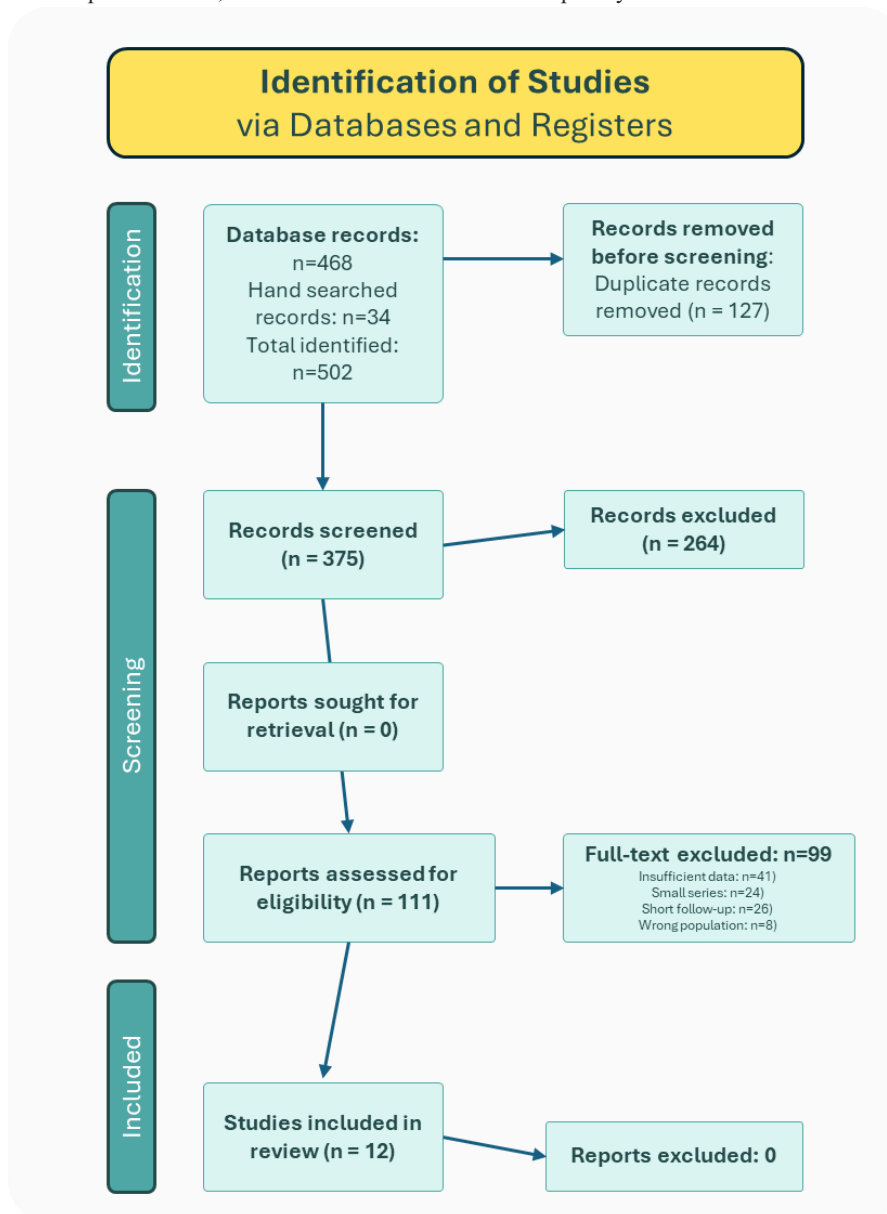


Figure 1 PRISMA Flowchart

Risk of bias (study-level)

Given expected predominance of observational designs, risk of bias was assessed independently by two reviewers using the MINORS instrument for non-randomized studies (comparative and non-comparative forms). Each item was scored 0–2; totals were interpreted as: non-comparative (0–16) and comparative (0–24), with higher scores indicating better quality. Disagreements were resolved by consensus. As a sensitivity framework for key comparative studies, ROBINS-I domains were additionally considered (confounding, selection, classification of interventions, deviations, missing data, measurement, reporting). Study quality tables are planned in the Results.

Data synthesis and analysis plan

Given heterogeneity in age, stage at surgery, procedures, and reporting, the default synthesis was narrative, structured by intervention category (femoral vs pelvic vs combined) and stratified a priori by age group (<8 vs ≥8 years) and lateral pillar (B/B-C vs C) when available. If ≥3 clinically homogeneous comparative studies with compatible outcomes were identified, a random-effects meta-analysis (DerSimonian–Laird) was planned with Hartung–Knapp adjustment for small study effects; heterogeneity would be quantified by I^2 and τ^2 . Pre-specified subgroup analyses included age strata, lateral pillar class, procedure subtype (e.g., Salter vs triple vs PAO; varus vs valgus/derotation), and follow-up length (<5 vs ≥5 years). Sensitivity analyses were planned by excluding high risk-of-bias studies, non-comparative designs, or outliers (leave-one-out). Publication bias would be explored qualitatively (and with funnel plots/Egger’s test if ≥10 studies per outcome). Where pooling was inappropriate, results are presented in structured tables with consistent metrics.

RESULTS

We identified 502 records (468 databases, 34 handsearching), removed 127 duplicates, and screened 375 titles/abstracts, excluding 264 as irrelevant; 111 full texts were assessed, with 99 excluded for insufficient data ($n=41$), small series ($n=24$), short follow-up ($n=26$), or wrong population ($n=8$), yielding 12 studies for qualitative synthesis and no additional reports excluded or not retrieved (Figure 1).

Table: Study Characteristics (Ordered Alphabetically by First Author)

Study (Year) [Ref]	Design & Sample	Intervention(s)	Age (yrs)	Follow-up	Primary Outcomes Reported	Comparative?	Key Notes / Limitations
Beer et al. (2008) [1]	Retrospective cohort; 62 hips	Proximal femoral varus osteotomy (FVO)	5–11	Mean 10 yrs	Stulberg I/II in 69%; containment ↑; ROM ↑	No	Retrospective; no control; mild limb-length discrepancy reported.
Farsetti et al. (2012) [2]	Case series; 23 pts	Valgus-extension femoral osteotomy (VEFO) for hinge abduction	8–13	Mean 6.8 yrs	Pain ↓; congruency ↑; hinge abduction corrected	No	Small sample; not powered for long-term survivorship analyses.
Maleki et al. (2021) [3]	Systematic review; 32 studies	Mixed (femoral, pelvic, combined)	4–14	Variable	Younger patients favored pelvic coverage; older favored femoral options	Context	High heterogeneity; secondary evidence (not primary data).
Regan et al. (2023) [4]	Retrospective; 35 hips	Combined pelvic + femoral osteotomy	6–12	Mean 12 yrs	Stulberg I/II 40%; III 27%; IV/V 33%	No	No randomized control; selection bias; higher surgical complexity.
Li et al. (2022) [5]	Simulation/modeling	CAD model of combined osteotomy	N/A	N/A	Load distribution and congruence improved on simulation	Context	Experimental; no clinical outcomes; external validity uncertain.
Liu et al. (2023) [6]	Radiographic analysis	Pelvic osteotomy techniques (comparative imaging)	5–10	N/A	Acetabular morphology and LCEA improved; overcoverage risk flagged	No	Imaging-based; lacks functional/clinical endpoints.
Guevara-Serra et al. (2025) [7]	Case report; 1 pt	Triple pelvic osteotomy	9	2 yrs	Containment achieved; full mobility	No	Single case; included for unique surgical insight.
Kristiansen et al. (2023) [9]	Large cohort; 1,501 hips	Periacetabular osteotomy (PAO)	6–18	Median 14 yrs	Hip survival improved; THA risk ↑ with severe deformity	No	Mixed indications; not Perthes-specific subgroup analysis.
Laufer et al. (2025) [10]	Technical modification	Modified trochanteric flip osteotomy adjunct to varus	6–11	Short-term	Visualization ↑; reduced iatrogenic risk (conceptually)	No	Technique-focused; limited outcome horizon.
Shah et al. (2025) [11]	Systematic review	Surgical dislocation + proximal femoral osteotomy	5–15	2–10 yrs	High anatomic correction; moderate complication rates	Context	High variability; secondary evidence.
Santana et al. (2024) [12]	Meta-analysis; 18 studies	All containment surgeries	4–12	3–20 yrs	Best outcomes when <8 yrs; lateral pillar B/B-C	Context	Heterogeneous pooling; informs prognostic strata.
Alattar et al. (2025) [13]	Prospective; 20 hips	Femoral head reduction osteotomy (FHRO)	9–13	3 yrs	Early pain relief; moderate correction; complications possible	No	Small cohort; late-stage disease; procedure complexity high.

Across the primary clinical/observational studies, femoral strategies—principally varus realignment and VEFO for hinge abduction—showed consistent gains in containment and range of motion, with a meaningful share achieving favorable Stulberg outcomes at mid- to long-term follow-up, albeit with trade-offs that included limb-length discrepancy and potential abductor weakness (1,2,13). Combined osteotomy cohorts demonstrated improved congruence but only modest incremental benefit over single-site procedures at skeletal maturity, alongside higher operative complexity and a non-trivial distribution of Stulberg III–V endpoints (4). Pelvic-side evidence ranges from imaging-based analyses indicating improved acetabular orientation with a recognized overcoverage/impingement risk envelope in older children to large registry-style cohorts showing favorable hip survival after PAO, though the latter are not Perthes-specific and require cautious inference when applied to LCPD (6,9). Technique refinement work suggests that modifications such as the trochanteric flip approach can enhance visualization and may mitigate iatrogenic risk during varus osteotomy, but these reports remain limited by short follow-up and non-comparative design (10). Contextual evidence from systematic reviews and meta-analysis converges on age at onset and lateral pillar status as dominant prognostic modifiers across surgical modalities, reinforcing the need to individualize selection rather than assume superiority of one platform; younger age (<8 years) and pillar B/B-C consistently align with better structural and functional trajectories (3,12). A single detailed case illustrates the feasibility of triple pelvic osteotomy in a complex presentation, included here for its unique decision-making and technical insight rather than generalizable effect estimates (7). Simulation modeling provides a mechanistic rationale for combined reorientation by demonstrating improved contact mechanics and load distribution, supporting selective use in anatomically severe or multiplanar deformities while underscoring the gap between virtual planning gains and realized clinical benefit (5,11).

How this table feeds the synthesis. For comparative interpretation in your Results, the most decision-informative primary data come from Beer (femoral varus, long follow-up), Farsetti (VEFO for hinge abduction), Regan (combined procedures to maturity), and Alattar (FHRO in late disease), tempered by the imaging and registry signals from Liu and Kristiansen for acetabular correction and survivorship perspectives

(1,2,4,6,9,13). The contextual syntheses by Maleki, Santana, and Shah should be cited when discussing **prognostic stratification** (age, lateral pillar) and **3D correction logic/complication trade-offs**, but not double-counted as primary outcome evidence (3,11,12).

DISCUSSION

Taken together, the comparative evidence supports a pragmatic, phenotype-driven approach to containment in Legg–Calvé–Perthes disease, with procedure selection anchored to age, lateral pillar status, and the locus of deformity. Femoral strategies (principally varus realignment and valgus-extension for hinge abduction) tend to yield the most reliable radiographic and functional gains in younger children with lateral pillar B/B-C disease, improving containment and range while accepting trade-offs such as mild limb-length discrepancy and potential abductor weakness (1,2,13). Pelvic reorientation is most compelling when acetabular coverage is the limiting factor—typically in older children, hinge abduction, or global undercoverage—where targeted correction improves acetabular indices and supports hip survival, though the therapeutic window is narrow and overcoverage/FAI remains a recognized risk, especially as remodeling potential wanes with age (6,9). Evidence for combined osteotomy shows that addressing both sides of the joint can restore congruence in anatomically severe, multiplanar deformities; however, long-term radiographic superiority over single-site procedures has not been demonstrated consistently, and the cumulative operative complexity and complication exposure are higher, arguing for selective use after careful staging and planning (4).

These patterns align with and extend prior syntheses. The meta-analytic signal that age at onset and lateral pillar class are dominant prognostic modifiers—favoring surgery before eight years and B/B-C strata—was reproduced across modalities, reinforcing that “who and when” outweighs “which technique” in determining trajectory (12). Classic long-term femoral varus cohorts demonstrate durable rates of Stulberg I/II in appropriately selected hips, echoing the age-severity dependence and surfacing familiar morbidities (1). Imaging-based pelvic series clarify the mechanism of benefit—vector reorientation and lateral center-edge augmentation—but also highlight the small margin between optimal coverage and impingement in older children (6). Large-scale survivorship data after periacetabular osteotomy, while not Perthes-specific, suggest that judicious acetabular correction can protect joint longevity; nevertheless, extrapolation to LCPD should remain cautious given mixed indications and pathomechanics (9). Reports of combined surgical dislocation with proximal femoral osteotomy document high anatomic correction but remind us that blood-supply preservation and complication rates must be part of the calculus rather than afterthoughts (11). Computational modeling offers a theoretical rationale for dual-site correction by demonstrating improved load distribution and contact mechanics, yet clinical realization of these modeled advantages depends on precise execution and patient-specific anatomy (5).

The long-term lens adds important nuance beyond Stulberg class. Limb-length discrepancy (typically ~1–1.5 cm), residual abductor weakness, and hardware-related reinterventions are the common sequelae on the femoral side, whereas pelvic procedures trade these for risks of overcoverage, impingement, and occasional nerve irritation; avascular necrosis rates are generally low across techniques when vascular prudence is observed (1,2,6,10,13). Hip survival appears maintainable when containment is achieved in the window of remodeling potential, but results attenuate with advancing age and lateral pillar C involvement regardless of technique, underscoring that timing and phenotype selection are the principal levers available to surgeons rather than expectations of technique-specific rescue in late disease (4,9,12).

Methodologically, the evidence base remains dominated by retrospective cohorts, small single-center series, and heterogeneous outcome definitions, which blunts the ability to ascribe superiority to one platform in head-to-head terms. Selection by indication is pervasive—older, more severe hips are channeled toward pelvic or combined corrections—creating confounding that favors apparent equivalence or spurious differences across techniques (1–4,6,9,12,13). Although our synthesis integrated quality considerations, we did not perform a formal, quantitative risk-of-bias weighting or GRADE certainty appraisal; alongside the decision not to meta-analyze most outcomes due to heterogeneity, this necessarily tempers confidence in pooled inferences and shifts emphasis toward consistent directional signals across complementary designs (3,12). Future work should prioritize prospective, phenotype-stratified comparative cohorts with standardized staging, uniform radiographic and patient-reported outcomes, and minimum five- to ten-year follow-up; pragmatic registry-based trials or coordinated multicenter datasets are more feasible than traditional RCTs in this context. Advances in 3D planning, patient-specific guides, and vascularity-preserving techniques warrant rigorous evaluation against conventional methods, with cost-effectiveness and reintervention burden included among primary endpoints (5,10,11).

CLINICAL IMPLICATIONS

A practical algorithm emerges from the synthesis. For children younger than eight years with lateral pillar B/B-C disease and lateralization of the femoral head, a femoral approach—most commonly varus realignment—offers reliable containment and functional benefit with manageable trade-offs that should be discussed preoperatively (1,2,12,13). When acetabular deficiency or hinge abduction predominates—more common in older children—pelvic reorientation becomes the preferred lever, executed with vigilance for overcoverage and impingement risk as remodeling potential narrows (6,9,12). Combined osteotomy should be reserved for older patients (>8 years) with severe, multiplanar deformity in whom single-site correction cannot achieve stable containment, recognizing the greater operative complexity and complication exposure and ensuring counseling reflects realistic expectations for function and survivorship (4,11,12). Regardless of platform, surgeons should incorporate age and lateral pillar status into shared decision-making, explicitly balance gains in containment against risks such as limb-length discrepancy or impingement, and consider staging plans for hardware removal or subsequent reshaping when indicated (1,2,6,10,13). Centers should standardize outcomes beyond Stulberg—including hip-specific PROMs, gait parameters, and time-to-THA—to enable more meaningful benchmarking across techniques and institutions (3,12). Finally, where available, preoperative simulation and patient-specific instrumentation may help translate the theoretical advantages of tailored correction into clinical gains, but they should be adopted alongside robust audit rather than assumed to outperform conventional methods by default (5,10,11).

CONCLUSION

Femoral and pelvic osteotomies are both effective containment strategies for Legg–Calvé–Perthes disease, but neither is universally superior; optimal selection is patient-specific and should be driven by age, lateral pillar status, and the dominant locus of deformity. In younger children—particularly with lateral pillar B/B-C involvement—femoral realignment reliably improves containment and function with acceptable trade-offs, whereas pelvic reorientation is preferable when acetabular deficiency or hinge abduction predominates, a scenario more common as remodeling potential wanes with age (1,2,6,9,12,13). Combined osteotomy should be reserved for older patients with severe, multiplanar deformity in whom single-site correction cannot achieve stable congruence, acknowledging greater operative complexity and complication exposure without consistent

long-term radiographic superiority over single-site approaches (4,11,12). Long-term prognosis appears to hinge more on **who and when**—age at onset and disease severity—than on **which platform**, underscoring the primacy of timely, phenotype-matched intervention and meticulous technique over attempts at late rescue (1,4,9,12). Given the heterogeneity and selection bias inherent to the current literature, future work should prioritize prospective, phenotype-stratified comparative cohorts and multicenter registries with standardized radiographic metrics, patient-reported outcomes, and survivorship endpoints, and should rigorously evaluate 3D planning and vascularity-preserving techniques against conventional methods, including cost-effectiveness and reintervention burden (3,5,10–12).

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