Hypothesis

Hypothesis-Driven Patient Selection in Perthes Shelf Acetabuloplasty: Slip-In Index Threshold as a Prognostic Tool

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Abstract

Background: Legg–Calvé–Perthes disease is a childhood disorder in which blood flow to the femoral head is temporarily interrupted, causing bone death that is followed by a slow phase of collapse and repair. When the weakened femoral head is not well supported by the hip socket during healing, it can flatten and lose its round shape, which impairs motion and raises the risk of early arthritis. Children who are older at the time of onset or who present late in the disease course have less ability to remodel the head back to a spherical shape, so surgeons often consider procedures that improve containment of the femoral head while healing occurs.

Hypothesis: In older children whose femoral head is extruded but still reducible into the socket, lateral shelf acetabuloplasty — a surgery that builds out the outer rim of the acetabulum with bone graft — will increase lateral coverage and reduce lateral migration of the head. By creating better support during the reparative phase, the procedure should encourage a more spherical healed femoral head, preserve pain-free range of motion, and produce improved functional outcomes at medium-term follow-up when compared with the expected natural history for similar late-presenting hips.

Clinical importance: Shelf acetabuloplasty protects a vulnerable femoral head without changing femoral anatomy. By improving how the socket covers and supports the head, the operation can reduce pain, maintain hip motion and increase the chance of near-normal remodeling. This approach is particularly useful when altering the femur (for example, with a varus osteotomy) carries unwanted consequences such as limb-length or alignment changes. Careful preoperative assessment of reducibility and realistic counselling about the remodeling process are essential.

Future research: Prospective multi-centre studies that compare shelf acetabuloplasty with femoral and other pelvic containment procedures are needed, with long-term follow-up into adulthood. Incorporating three-dimensional imaging, objective gait and biomechanical measures, and standardized patient-reported outcomes will help identify which patients benefit most. Such studies will guide clearer, evidence-based decisions and improve long-term hip health for affected children globally.

Keywords: Legg–Calvé–Perthes disease, Shelf acetabuloplasty, Containment, Femoral head sphericity, Pediatric hip, Late presentation.


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Background

Legg–Calvé–Perthes disease (LCPD) is a childhood disorder in which blood supply to the femoral capital epiphysis is disrupted, producing necrosis followed by a prolonged phase of resorption and new bone formation. The final shape of the femoral head after this healing process largely determines future pain, motion and risk of early osteoarthritis. Early pathological descriptions and later clinical series make clear that age at onset and the extent of epiphyseal involvement are the main predictors of outcome: younger children with limited involvement usually remodel well, whereas older children and those with extensive necrosis face a much higher chance of permanent deformity [1,2].

Microscopically and biomechanically, the weakened femoral head succumbs to body weight and muscular forces during revascularisation; collapse or subchondral fracture leads to flattening and loss of sphericity if the head is not adequately supported. This mechanical vulnerability provides the rationale for treatments that protect and contain the head while remodelling proceeds [3,4].

Initial management ranges from simple observation, activity modification and physiotherapy to bracing; these conservative measures remain appropriate for many young children with limited disease. But when the femoral head is extruded, subluxated or the child is older at onset, spontaneous remodelling is less reliable and surgical containment is commonly considered to limit progressive deformity [5,6].

Surgical containment falls into two broad strategies: femoral procedures and pelvic/acetabular procedures. Femoral varus or valgus osteotomies work by repositioning the femoral head under the native acetabular roof, which can be effective in certain age groups but permanently alters proximal femoral geometry and can cause leg-length or gait issues in some cases [7, 8]. Pelvic procedures — including Salter innominate osteotomy, triple osteotomy and shelf acetabuloplasty — instead change the acetabular support. These options aim to improve lateral coverage without disturbing the femur itself, an advantage in older children where femoral geometry should ideally be preserved [9,10].

Shelf acetabuloplasty has a straightforward mechanical logic: by extending the lateral acetabular rim with a graft, a larger lateral roof is created to keep an extruded or partially subluxated head contained while biology does its work. Increasing contact area and moving load away from a weakened lateral epiphysis reduce the tendency to collapse and flatten, thereby promoting a more spherical remodeling pattern. Early and medium-term clinical series have reported improved radiographic coverage indices and favourable morphological results in many patients treated with shelf procedures, particularly when the head remains reducible and the procedure is performed before irreversible deformity is established [11,12].

Compared with some pelvic osteotomies, the shelf is often technically simpler and avoids an osteotomy through the innominate bone, while still increasing lateral support. That practical simplicity has made shelf acetabuloplasty a popular option for older children and late presenters with Perthes disease — cases where femoral osteotomy may be less desirable. Nonetheless, outcomes depend heavily on careful selection: a reducible head, adequate joint motion, and an acetabular shape that can accept an augmentation without producing impingement are prerequisites for success [13,14].

Because LCPD evolves over years, meaningful assessment of any containment strategy requires medium- to long-term follow-up. Radiographic endpoints (coverage measures, migration indices) and final morphologic grading (such as Stulberg classification) are commonly used to judge success, along with clinical measures of pain and function. The thesis under review reports a consecutive series of older children treated with lateral shelf acetabuloplasty and examines radiographic coverage, morphological outcome and clinical function — adding a focused dataset to the ongoing debate about containment choice in older, late-presenting hips [15, 16].

Hypothesis

Primary hypothesis

In older children and late presenters with Legg–Calvé–Perthes disease who have an extruded but reducible femoral head, lateral shelf acetabuloplasty will (1) produce a measurable increase in lateral acetabular coverage and reduce lateral migration, and (2) lead to improved morphological outcomes and clinical function at medium- to long-term follow-up when compared with the expected natural history for similar age/stage cohorts.

Why this hypothesis is reasonable

Perthes disease presents a period in which the femoral head is biologically active but mechanically weak. Changing the mechanical environment during this window can alter remodeling forces and ultimately the healed shape of the head. Augmenting the lateral acetabular rim with a shelf graft increases coverage and spreads contact forces across a larger area, diminishing focal stress on vulnerable lateral subchondral bone and lowering the chance of progressive collapse. Prior series and reviews have documented radiographic gains in coverage and satisfactory Stulberg outcomes after shelf procedures in appropriately chosen patients, supporting the mechanistic rationale behind this hypothesis [17,18].

Why target older children and transitional hips?

Older children (commonly defined as those >8 years at onset) have less intrinsic capacity for spontaneous remodeling and a higher likelihood of poor natural history outcomes. Femoral varus osteotomy remains an option but may introduce permanent femoral alignment changes and limb-length effects that are undesirable in older children where remodelling

potential is limited. A shelf procedure offers lateral containment without altering femoral anatomy, making it a particularly attractive option in this subgroup [19, 20].

Specific, measurable predictions (endpoints)

1. Radiographic: A statistically significant postoperative increase in standard lateral coverage measures (for example, center-edge angle or migration index equivalents used in the thesis) and a reduction in lateral displacement compared with preoperative baselines. These changes will be evident on serial radiographs taken from immediate postoperative to latest follow-up [21].
2. Morphologic: At medium-term follow-up or skeletal maturity, the majority of hips will achieve favourable Stulberg-type grades (I–III) rather than poor grades (IV–V), shifting the distribution towards better sphericity than expected from natural history for similar late-presenting cohorts [22].
3. Clinical: Patients will report reduced pain, improved or preserved hip range of motion (notably abduction and internal rotation), and acceptable functional scores consistent with activities of daily living and school/play participation [23].
4. Safety: The procedure will have low rates of major complications (no frequent need for reoperation, acceptable graft incorporation with minimal clinically relevant migration and no significant limb-length discrepancy attributable to the surgery) [24].

Selection and timing rationale

The shelf assumes a reducible head that will sit under the augmented rim; therefore, preoperative dynamic assessment (arthrography or careful radiographic/dynamic examination) matters. Earlier containment, when the head is still salvageable, tends to produce better morphological outcomes than late salvage, so timing—balanced with realistic assessment of reducibility—is central to testing this hypothesis [25].

Discussion

What the thesis series demonstrates

This single-centre consecutive series reports consistent improvements in acetabular coverage indices after lateral shelf acetabuloplasty, a reduction in lateral migration and generally favourable morphological outcomes at follow-up. Many hips reached acceptable Stulberg-type grades and most patients experienced pain relief and preserved motion at their latest assessments.

Compared with femoral varus osteotomy, shelf procedures avoid changing femoral anatomy and thus spare issues such as limb-length discrepancy or altered gait mechanics — advantages particularly relevant in older children where remodeling is limited and femoral geometry should be preserved [3, 4].

Strengths and methodological caveats

Strengths of the study include a clearly described operative technique, consistent follow-up with serial radiographs, and a consecutive cohort that reduces selection bias. However, as with many surgical retrospective series, the absence of a randomized or matched control group limits causal claims. Two-dimensional radiographs were the primary imaging modality, which constrains full volumetric assessment of femoral head sphericity and acetabular congruence compared with three-dimensional imaging. Single-surgeon experience improves technical consistency but may reduce generalisability. These limitations should temper the interpretation of favorable outcomes [5, 6].

Mechanistic considerations and practical application

Biomechanically, increased lateral support from a shelf graft redistributes load and reduces focal collapse risk, allowing the biologic reparative phase to produce a more regular ossification pattern. Clinically, this mechanism is reflected in better containment on radiographs, improved abduction and internal rotation, and less pain during follow-up visits. Graft resorption or partial remodeling of the shelf is common but often clinically acceptable if net coverage and joint mechanics remain improved [7, 8].

Where shelf is most useful — and its limits

The shelf is most helpful when the head is extruded but reducible and when preserving femoral anatomy is desirable. It is less effective for grossly deformed, non-reducible heads or hips with irreversible collapse; in those situations, reconstructive or salvage options (including later arthroplasty in adults) might be the only effective solutions. Thus, careful preoperative evaluation to establish reducibility and residual joint motion is crucial to avoid futile operations [9, 10].

Implications for surgeons and patients

For surgeons treating late-presenting Perthes hips, the shelf represents a practical containment procedure that can shift the balance toward better morphological and functional outcomes without the morbidity associated with femoral geometry alteration. Patient selection, realistic counselling about expected remodeling and the need for multi-year follow-up remain central to achieving good results [11, 12].

Clinical importance

Shelf acetabuloplasty is a useful surgical option for older children and late presenters with Perthes disease when the femoral head is extruded but reducible. By increasing lateral acetabular coverage, it reduces eccentric loading on a weakened head, preserves hip motion, and frequently results in improved head sphericity at follow-up — outcomes associated with better function and potentially delayed degenerative change. Because

the operation does not alter proximal femoral anatomy, it avoids limb-length and alignment consequences that sometimes follow femoral osteotomies. Careful selection, thorough preoperative assessment of reducibility, and long-term follow-up are essential to secure durable benefits.

Future directions

Future research should prioritize prospective, multi-centre comparative studies that match patients by age and disease stage to determine which hips benefit most from shelf versus femoral or other pelvic osteotomies. Long-term follow-up into adulthood is necessary to confirm whether improved intermediate sphericity after shelf indeed reduces osteoarthritis and the need for hip replacement. Incorporating three-dimensional imaging (MRI/CT), quantitative cartilage assessment, and objective gait/biomechanical analysis will refine selection criteria and provide clearer measures of true joint congruence beyond plain radiographs. Finally, harmonizing outcome measures across studies will let meta-analyses guide evidence-based choices for containment strategies in late-presenting Perthes disease.

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