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Original Article

Mean Length of Femoral Shortening Required in DDH Patients

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ABSTRACT

Walking-age children with developmental dysplasia of the hip (DDH) frequently exhibit severe dislocation and soft tissue contractures, making concentric, tension-free reduction difficult. However, it is still unclear exactly how much femoral shortening is necessary and what factors influence it. **Objectives:** The goal is to ascertain the average length of femoral shortening needed for open reduction in pediatric patients with DDH and to find radiographic and clinical indicators of the extent of shortening. **Methods:** From February to August of 2025, a descriptive observational cohort study was carried out. There were 46 kids (52 hips) with IHDI grades III–IV DDH. Standard anterior open reduction with routine soft tissue releases was performed, and femoral shortening was applied intraoperatively when reduction under excessive tension was observed. Postoperative outcomes were assessed. **Results:** The mean femoral shortening required was 2.34 ± 0.56 cm (95% CI: 2.18–2.50). Grade IV dislocations required significantly greater shortening (2.51 ± 0.49 cm) than grade III (1.92 ± 0.41 cm, p = 0.001), and children older than 36 months required more shortening (2.63 ± 0.45 cm) compared to younger children (1.98 ± 0.44 cm, p<0.001). Age, side, and IHDI grade IV were independent predictors. **Conclusions:** In children aged 1–8 years with IHDI III–IV DDH, the mean femoral shortening required for stable, tension-free reduction was 2.34 cm, with older age and higher-grade dislocations predicting greater shortening. Tailored, intraoperative determination of shortening length achieves excellent short-term outcomes with minimal complications, supporting its selective use in pediatric DDH surgery.

INTRODUCTION

Inadequate treatment for developmental dysplasia of the hip (DDH), which spans from mild acetabular dysplasia to frank dislocation, can lead to early hip osteoarthritis [1, 2]. Soft tissue contracture, proximal femur migration, and acetabular dysplasia make concentric, tension-free reduction technically challenging and raise the risk of avascular necrosis (AVN), redislocation, and residual dysplasia when diagnosis is postponed past infancy [3, 4]. Based on a comprehensive 2023 systematic review and meta-analysis with over 3.4 million participants, the literature shows that DDH is still a clinically important disorder with a pooled prevalence of about 1.4% among babies [1]. Studies also highlight the fact that, despite DDH being one of the most prevalent hip diseases in children, there is still a dearth of high-level information supporting the best surgical choices, especially with relation to femoral shortening and its measurement [2]. The standard approach for achieving stable reduction and restoring hip biomechanics in walking-age children is open reduction in conjunction with pelvic and/or femoral osteotomies [1, 2, 4]. By avoiding excessive leg lengthening and capsular tension, femoral shortening (FS), typically through a subtrochanteric osteotomy, is used to reduce soft tissue tension across the reduced hip, facilitate reduction, and possibly lower the risks of AVN and redislocation [3, 5] Adjunctive femoral osteotomy, including shortening, is

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linked to improved stability and decreased AVN in high dislocations and older children, according to a large series of late-presenting DDH treated with open reduction and pelvic osteotomy [2, 4]. However, FS is not universally required, and its indications remain debated. In a cohort of 645 hips treated after walking age, hips managed without FS showed slightly better functional scores and a higher proportion of good/excellent Severin outcomes. However, FS was more frequently used in older children with more severe displacement [1]. A separate series of 712 hips undergoing open reduction (with or without pelvic osteotomy) reported excellent long-term function and low redislocation rates. However, their utilization of FS was limited to only a small number of patients and in the same group, with the presence of high-grade dislocations and greater superior subluxation [2]. The requirement for FS depends greatly on patient age, gender, and the amount of displacement of the femoral head (IHDI/Tönnis grade), which is confirmed by predictive studies on pediatric DDH patients and stresses the importance of preoperative risk analysis and personalized treatment plans [3, 6]. Simultaneous bilateral FS in patients diagnosed late bilaterally with DDH can result in good radiological results, acceptable initial functional performance, with minimal instances of AVN and redislocation, based on recent research from single-stage triple procedures (ORIF, acetabuloplasty, femoral shortening) [5, 7]. Femoral shortening osteotomy often becomes an integral part of total hip arthroplasty (THA) for patients suffering from Crowe III-IV DDH, as the procedure helps to relocate the hip joint into the true acetabulum while avoiding any leg lengthening and sciatic nerve damage. Numerous techniques, such as transverse osteotomies, oblique osteotomies, and Z-osteotomies, used together with cemented and cementless stems, have proven to be highly effective in terms of increasing Harris Hip Score, eliminating any leg length discrepancy, and significantly reducing pain. Moreover, there are virtually no cases of nonunion or permanent nerve damage reported during long-term and mid-term follow-ups [8-14]. The long and mid-term outcomes studies demonstrate that THA with femoral shortening osteotomy exhibits good survivorship, with the majority of revision operations performed due to acetabular wear or loosening, not osteotomy failure [10, 13, 14].

The difficulty with this technique lies in the fact that children suffering from developmental dysplasia of the hip have high dislocation and tissue contractures. However, the actual amount required is not very standardized since femoral shortening is a common method used to ensure tension-free reduction. From the clinical standpoint, the measurement of the mean femoral shortening is important since it allows for intraoperative decisions and planning while reducing possible complications like avascular necrosis and redislocation. The importance of having an objective value for this group of patients arises from the fact that most of the literature available today deals with the rationale for shortening and not with how much shortening should be done. The objective of this study was to measure the mean amount of femoral shortening needed for children diagnosed with developmental dysplasia of the hip(DDH).

METHODS

This Descriptive Observational Cohort study was carried out at the Department of Orthopaedics and Spine Centre, Ghurki Trust Teaching Hospital, Lahore, from February 2025 to August 2025. The study was conducted with the approval of the Institutional Review Board [Ref No.2025/02/R-08, Dated:04-02-25] and followed the Declaration of Helsinki. With a 90% confidence interval, a 10% margin of error, and an estimated proportion of patients with a need for femoral shortening of 21.7%, a sample size of 46 hips was calculated. As in this study, femoral shortening was required in 119 hips out of 548 hips that why this proportion value was calculated [3]. All parents/legal guardians gave written informed consent. Hospital records were analyzed to identify consecutive pediatric patients diagnosed with DDH and undergoing primary anterior open reduction during the study period. Patients aged between 1 and 8 years with International Hip Dysplasia Institute (IHDI) grade III or IV dislocation were included. Only those with complete operative and radiographic records and a minimum follow-up of six months were enrolled. Patients with non-idiopathic hip dislocation secondary to neuromuscular or syndromic conditions, revision cases, patients younger than 1 year or older than 8 years, IHDI grade I or II dislocations, and those managed through a medial surgical approach were excluded from the study. All procedures were performed using a standard anterior approach to the hip. Routine soft tissue releases included adductor longus, rectus femoris, and iliopsoas tenotomies. The decision to perform femoral shortening was made intraoperatively based on the inability to achieve concentric reduction or when reduction was achieved under excessive tension. Femoral shortening was carried out through a separate lateral incision using a subtrochanteric transverse osteotomy. The decision to perform femoral shortening and the amount to be resected were based on a standardized intraoperative protocol. Following routine soft tissue releases, the femoral head was reduced into the acetabulum. Tension was assessed qualitatively by the operating surgeon using the following criteria: (1) inability to maintain concentric reduction without excessive force, (2) visible tension in the surrounding soft tissues during hip range of motion testing

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(specifically, inability to achieve ≥30° of flexion or ≥10° of abduction without displacement of the reduced head), and (3) the presence of a palpable 'spring-back' sensation when traction was released. When any of these criteria were met, a subtrochanteric osteotomy was performed. The shortening amount was determined by sequentially resecting 0.5 cm segments of bone until the above criteria were no longer present and the reduced hip could be taken through a full range of motion (at least 45° flexion and 15° abduction) without tension or displacement. The total resected segment was measured using a sterile ruler and documented. All procedures were performed or directly supervised by a single senior surgeon (or X number of surgeons with ≥Y years of experience) to minimize inter-operator variability. The assessment of tension was performed using a consistent technique throughout the study period. Pelvic osteotomy was added when indicated. There was no use of preoperative traction. The mean length (in centimeters) of femoral shortening necessary to accomplish stable and tension-free hip reduction served as the main outcome measure. Postoperative limb length discrepancy, radiographically determined avascular necrosis (AVN), Shenton's line disruption, recurrence or redislocation, deep surgical site infection, and other postoperative complications were among the secondary outcomes. Radiographic assessments were performed using standardized anteroposterior pelvic radiographs obtained immediately postoperatively and at final follow-up (immediate post op). However, assessors were not blinded to clinical details, which may introduce observer bias. Additionally, inter- and intra-observer reliability for radiographic measurements and femoral shortening assessment were not formally evaluated, representing a potential source of measurement variability. Representative preoperative and postoperative radiographs and scanograms were obtained to document hip reduction, osteotomy fixation, and postoperative limb length alignment. Preoperative and immediate postoperative anteroposterior (AP) pelvis radiographs of a child with right-sided developmental dysplasia of the hip (DDH) treated with open reduction and femoral shortening osteotomy. (A) Preoperative AP pelvis radiograph demonstrating an IHDI grade IV dislocation of the right hip with marked superolateral displacement of the femoral head and disruption of hip joint congruity. (B) Immediate post-operative AP pelvis radiograph showing a successful concentric reduction of the femoral head into the acetabulum. The procedure done is an open reduction and subtrochanteric femoral shortening osteotomy with plate fixation (Figure 1).

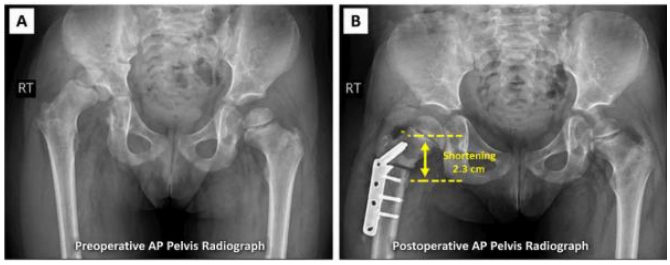


Figure 1: Pre- and Postoperative Views of AP Pelvis X-Rays on Right DDH Treated by Femoral Shortening Osteotomy. (A) Preoperative IHDI Grade IV Dislocation. (B) Radiograph Following Osteotomy and Internal Fixation

Scanogram showing the lower limb of a patient with right DDH following osteotomy and fixation of the femur. There is evidence of femoral shortening of around 2.5 cm to allow tension-free reduction. There is a satisfactory limb alignment with little difference in leg length and a reduction of the hip joint (Figure 2).

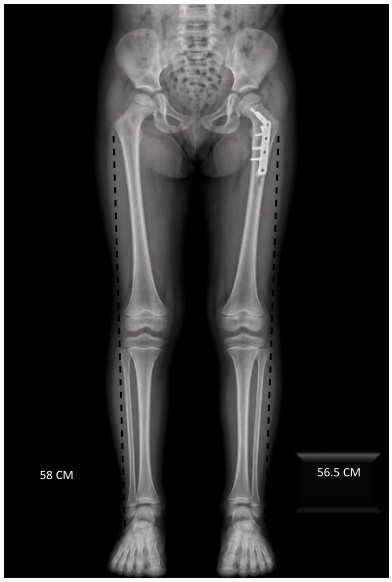


Figure 2: Lower Limb Scanogram of patient right sided DDH femoral shortening of 2.5cm

We recognize that the 6-month minimum follow-up period is comparatively short and might not be adequate to capture long-term outcomes like late-onset avascular necrosis, femoral overgrowth, or residual acetabular dysplasia. Nonetheless, this study's main goal was to assess early postoperative stability and complications, as well as the intraoperative requirement and mean length of femoral shortening. While follow-up to skeletal maturity was necessary to assess long-term growth-related changes, this was not part of this study. Further studies with a longer follow-up period are recommended, and this has been recognized. Measurement variability may have been introduced because there has been no reliability testing on the measurements, despite the standardization of the methods used. Age (in months), sex, side of

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involvement, body mass index (BMI), and IHDI grade were among the clinical and demographic factors that were noted. Radiographic evaluation before and after surgery using standardized anteroposterior pelvic radiographs was performed to assess hip reduction, alignment, and limb equality—analysis performed at the hip level. SPSS version 29.0 was used to analyze the data. Categorical variables were presented as frequencies and percentages, while continuous variables were presented as mean ± SD. Independent t-tests were used for comparison of continuous variables, while chi-square tests were used for categorical variables. To determine the variables linked to the necessary amount of femoral shortening, linear regression analysis was used. Normality of residuals and the absence of multicollinearity were checked with residual plots and variance inflation factors (VIFs) for the linear regression models. No formal adjustment for multiple comparisons was performed, as subgroup analyses were pre-specified and exploratory in nature and focused on clinically relevant variables. A p-value of < 0.05 was taken as the criterion for statistical significance.

RESULTS

The 46 patients (52 hips) in the study cohort ranged in age from 14 to 76 months, with a mean age of 37.2 ± 14.1 months. Involvement was slightly more common on the left side (53.8%), and the majority were female (78.3%). In this population, the majority of hips (73.1%) were categorized as IHDI grade IV, indicating severe dislocation (Table 1).

Table 1: Demographic and Clinical Characteristics (n = 52 hips, 46 patients)

Variables	Value
Number of patients	46
Number of hips	52
Mean age at surgery (months)	37.2 ± 14.1
Age range (months)	14 – 76
Sex	
– Female	36 (78.3%)
– Male	10 (21.7%)
Side of involvement (hips)	
– Left	28 (53.8%)
– Right	24 (46.2%)
IHDI Grade	
– Grade III	14 (26.9%)
– Grade IV	38 (73.1%)

For a stable, tension-free hip reduction, the overall mean femoral shortening required was 2.34 ± 0.56 cm (95% CI: 2.18–2.50). Hips with IHDI grade IV dislocations needed substantially more shortening (2.51 ± 0.49 cm) than grade III hips (1.92 ± 0.41 cm, $p<0.001$), according to subgroup analysis. In a similar vein, patients older than 36 months required more femoral shortening (2.63 ± 0.45 cm) than younger children (1.98 ± 0.44 cm, $p < 0.001$). There were no statistically significant differences according to sex (Table 2).

Table 2: Mean Femoral Shortening

Variables	Mean ± SD (cm)	95% CI	p-value
Overall mean shortening	2.34 ± 0.56	2.19 – 2.49	–
IHDI Grade			
Grade III (n=14)	1.92 ± 0.41	1.68 – 2.16	<0.001
Grade IV (n=38)	2.51 ± 0.49	2.35 – 2.67	
Age Group			
≤36 months	1.98 ± 0.44	1.80 – 2.16	<0.001
>36 months	2.63 ± 0.45	2.45 – 2.81	
Sex			
Female (n=36)	2.30 ± 0.53	2.12 – 2.48	0.337
Male (n=10)	2.49 ± 0.61	2.11 – 2.87	
Side			
Left (n=28)	2.36 ± 0.55	2.16 – 2.56	<0.001
Right (n=24)	2.32 ± 0.58	2.09 – 2.55	

Excellent short-term results were shown by postoperative evaluation; at the final follow-up, 96.2% of hips had concentric reduction. 3.8% of cases had redislocation, and 5.8% had avascular necrosis. No limb length differences larger than 2 cm were observed, and only one patient experienced a deep surgical site infection. The mean postoperative limb length discrepancy was minimal (0.61 ± 0.38 cm). These results indicate that femoral shortening, when appropriately indicated, is associated with stable reduction and a low complication profile (Table 3).

Table 3: Postoperative Outcomes and Complications

Outcomes	Frequency (%)
Concentric reduction at final follow-up	50 (96.2%)
Redislocation	2 (3.8%)
Avascular necrosis (AVN)	3 (5.8%)
Deep surgical site infection	1 (1.9%)
Limb length discrepancy > 2 cm	0 (0%)
Mean postoperative LLD (cm)	0.61 ± 0.38

Linear regression analysis identified age and IHDI grade IV as significant predictors of the length of femoral shortening required. Specifically, each additional month of age increased the shortening requirement by 0.041 cm ($p<0.001$), and grade IV hips required an additional 0.53 cm compared to grade III hips ($p=0.002$). Sex and side of involvement were not significant predictors. These findings reinforce that both patient age and dislocation severity should be considered in preoperative planning for femoral shortening (Table 4).

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Table 4: Linear Regression Analysis for Predictors of Femoral Shortening Length

Variables	β Coefficient	Standard Error	95% CI	p-value
Age (per month)	0.041	0.009	0.023 – 0.059	<0.001
IHDI Grade IV	0.530	0.160	0.216 – 0.844	0.002
Male Sex	0.180	0.120	-0.055 – 0.415	0.149
Right Side	-0.040	0.110	-0.256 – 0.176	0.742

DISCUSSION

Femoral shortening is typically 1 cm to 2 cm and is used to reduce tension, but does not necessarily lead to better outcomes. This study found that the mean femoral shortening required to achieve a stable, tension-free reduction in IHDI III–IV DDH was 2.34 ± 0.56 cm, with significantly greater shortening in older children and in IHDI grade IV hips. These findings complement current evidence that femoral shortening is primarily needed in late-presenting and high-grade dislocations as an adjunct to open reduction to reduce soft tissue tension and protect the femoral head from avascular necrosis (AVN) and redislocation [1-4]. In the largest available prognostic study of 548 hips, Alassaf reported that the probability of requiring femoral shortening increased with age (OR 1.11 per month) and IHDI grade IV, with male sex also emerging as an independent predictor [3]. The present cohort similarly demonstrates that each additional month of age increased the required shortening by 0.041 cm and that IHDI grade IV hips needed an additional 0.53 cm compared with grade III, reinforcing age and displacement severity as key determinants of the osteotomy magnitude rather than only its presence or absence. Local data from Pakistan also identified older age and high-grade DDH as major predictors of needing shortening, again underscoring the importance of late presentation and severe displacement in surgical planning [6]. Regarding indications, several authors advocate routine shortening beyond specific age/severity thresholds. Charki *et al.* recommended femoral shortening for Tönnis 3–4 hips in children >18 months, and multiple series have used shortening routinely after age ≥3–5 years in high-grade DDH [1, 4]. In contrast, Duan *et al.* reported that femoral osteotomy is not necessary for children aged 2–3 years with Tönnis III DDH, with similar AVN and redislocation rates whether or not shortening was performed [15]. The present results, showing a lower shortening requirement (mean 1.98 cm) in children ≤36 months and in IHDI III hips, align with this more selective approach and suggest that modest or no shortening may be adequate in younger, less displaced hips. The short-term outcomes in this cohort (96.2% concentric reduction, 3.8% redislocation, 5.8% AVN, no limb length discrepancy >2 cm) are at least comparable, and in some respects more favorable, than those reported in large series of late-presenting DDH managed with open reduction plus pelvic and/or femoral osteotomy. Charki *et al.* reported AVN in 20% and redislocation in 12% of 414 hips, with 72% achieving stable reduction without AVN [4]. Castaneda *et al.* observed redislocation rates of 6–14% and AVN rates similar to other reports. They noted that femoral shortening did not clearly improve long-term functional outcomes compared with non-shortened hips [1]. Other single-stage protocols combining open reduction, femoral shortening, and pelvic osteotomy in older children have yielded good or excellent radiological and clinical results in 60–80% of hips, but with AVN rates frequently above 10% and variable limb length discrepancy (LLD) at follow-up [16, 17]. The relatively low AVN and redislocation rates and minimal mean LLD (0.61 cm) in the present cohort suggest that tailoring the amount of shortening to obtain a tension-free reduction may help balance stability with preservation of growth potential. The age-shortening-length femoral overgrowth-LLD relationship has been gaining increasing attention. Pang *et al.* demonstrated that age at surgery was an independent risk factor for both femoral overgrowth ≥1 cm and LLD ≥1 cm following pelvic osteotomy and femoral shortening in unilateral DDH [16]. The DDH leg is also longer at maturity, as reported by Merchant *et al.* where the majority of the difference is the length of the subtrochanteric femur, and this is strongly influenced by femoral osteotomy and multiple surgeries [18]. Several significant predictors before the surgery were identified: age > 5 years, female gender, breech presentation, positive family history, and IDHI grade 4 for femoral shortening during open reduction in DDH. The lack of clinically relevant (>2 cm) LLD at short-term follow-up in this series is reassuring. However, a longer follow-up is needed to see if age-related overgrowth will compensate for this initial shortening or if there will be large differences later in childhood or adolescence. A major strength of this study is that the same surgical procedure, the uniform surgical procedure (primary anterior open reduction with a standard soft tissue release and subtrochanteric transverse shortening osteotomy when necessary), was performed on a precisely defined cohort of IHDI III–IV hips in children between the ages of 1 and 8 years. Decision for intraoperative tension-based shortening correlates well with real-world practice. It allows measuring the actual shortening length, which had not been done in previous studies, which mainly focused on whether shortening was performed or not. The shortening length is measured by the linear regression to provide new clinically useful data for pre-operative planning, which is the effect of age and IHDI grade [19]. Nonetheless, a number of limitations must be noted. The ability to conclude the advantages and disadvantages of femoral shortening is limited by the single-center, observational design that lacks a

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comparison group that is not treated with femoral shortening. The follow-up period (minimum 6 months) is insufficient to fully capture late complications like growth disturbance, femoral overgrowth, residual dysplasia, or the need for secondary procedures, which frequently appear years after surgery, and the sample size (52 hips) is small when compared to larger multicenter cohorts. In order to assess the long-term balance between initial shortening, femoral overgrowth, AVN, residual dysplasia, and functional outcomes, future studies should confirm these findings in larger, multicenter cohorts with longer follow-up to skeletal maturity. Counseling and surgical planning could be improved beyond current binary models by incorporating preoperative prediction models for the necessity and approximate length of femoral shortening based on age, IHDI grade, femoral head displacement, and proximal femoral morphology [20].

In spite of the advantages offered by the well-defined cohort and standardized operative procedure, some limitations were found with this study. Firstly, the lack of an untreated group does not allow for an assessment of the relative merits of femoral shortening techniques compared to non-shortening techniques. Secondly, the small sample size and limited follow-up period of at least six months do not allow for an assessment of long-term outcomes, such as femoral overgrowth, residual dysplasia, late avascular necrosis, and the need for secondary procedures. Thirdly, the intraoperative decision-making process based on the surgeon's judgment limits the study to some extent. As some patients contributed bilateral hips, the assumption of independence may be violated, potentially leading to underestimation of standard errors. Future studies need to focus on conducting larger studies with long-term follow-up to skeletal maturity to better understand the long-term outcomes of the procedure. Moreover, developing predictive models based on age, IHDI grade, femoral head displacement, and proximal femoral morphology will also help to improve preoperative planning. Further studies on the relative merits of selective femoral shortening techniques compared to routine femoral shortening will also help to develop standardized guidelines to optimize individualized treatment protocols for pediatric DDH.

CONCLUSIONS

In children aged 1–8 years with IHDI III–IV DDH, the average shortening required was 2.34 cm, and the short-term results revealed high rates of concentric reduction, low rates of redislocation and AVN, and little shortening. The short-term results support the use of intraoperative tailoring of subtrochanteric shortening in the surgical management of pediatric DDH.

Authors' Contribution

Conceptualization: SR
Methodology: SA
Formal analysis: AA, UA
Writing and Drafting: HH, UA, JUH
Review and Editing: SR, AA, HH, UA, JUH, SA

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflict of Interest

All the authors declare no conflict of interest.

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