Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Mid-term Outcomes and Factors Associated with Recovery after Total Hip Arthroplasty with Transverse Subtrochanteric Shortening Osteotomy for Crowe Type IV Developmental Dysplasia of the Hip

Yongqi Xia
Jining Medical University
Wenbo Meng
Jining Medical University
Jichao Bian
Affiliated Hospital of Jining Medical University
Long Yuan
Affiliated Hospital of Jining Medical University
Yuanmin Zhang
Affiliated Hospital of Jining Medical University
Guodong Wang
15106722107@163.com

Affiliated Hospital of Jining Medical University

Research Article

Keywords: Developmental dysplasia of the hip, total hip arthroplasty, Crowe type IV, leg-length discrepancy, subtrochanteric shortening osteotomy

Posted Date: November 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11383269/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background:

This study assessed mid-term outcomes after total hip arthroplasty (THA) with transverse subtrochanteric shortening osteotomy for Crowe type IV developmental dysplasia of the hip (DDH), and factors associated with functional recovery.

Methods:

We retrospectively reviewed 46 patients (53 hips) treated between 2014 and 2023. Mean age was 50.3 years and mean follow-up was 6.2 years. Clinical outcomes included Harris Hip Score (HHS), pain score, leg-length discrepancy (LLD), walking independence, abductor lurch, complications and revision. Radiographic outcomes included femoral offset, acetabular offset, cup inclination, cup anteversion and cup size. Kaplan-Meier analysis estimated implant survival. Correlation and multivariable linear regression assessed predictors of postoperative HHS.

Results:

HHS improved from 30.9 to 89.9, pain score from 4.7 to 1.4, and median LLD from 52.0 mm to 5.4 mm. Independent ambulation increased from 78.3% to 97.8%, and abductor lurch decreased from 69.6% to 10.9%. Acetabular offset decreased, femoral offset was maintained, and mean cup inclination and anteversion were 44.8 degrees and 14.6 degrees. Six revisions occurred, with 87.0% implant survival at 5 and 10 years. Cup inclination correlated negatively with postoperative HHS ($r = -0.418$, $P = 0.002$) and remained inversely associated with HHS after patient-level cluster-robust adjustment ($\beta = -0.359$ per degree, cluster-robust SE = 0.094, 95% CI, -0.549 to -0.169; $P = 0.0004$). Cup size was also inversely associated with postoperative HHS in the primary clustered model ($\beta = -0.641$ per mm, cluster-robust SE = 0.290, 95% CI, -1.225 to -0.057; $P = 0.032$). Cup inclination moderately discriminated suboptimal recovery (HHS < 80; AUC = 0.758), whereas residual LLD did not (AUC = 0.524).

Conclusion:

THA with transverse subtrochanteric shortening osteotomy provided substantial functional improvement, pain relief, limb-length correction and acceptable mid-term implant survival in Crowe type IV DDH. After patient-level clustering was accounted for, greater cup inclination remained inversely associated with lower postoperative HHS in this retrospective cohort, suggesting that careful attention to cup inclination may be warranted in complex dysplastic hip reconstruction. These findings are exploratory and should be validated in larger patient-level datasets.

Level of Evidence

Level III, retrospective cohort study

Introduction

Crowe type IV developmental dysplasia of the hip represents the most severe end of the dysplastic hip spectrum[1–3]. It is characterised by high-riding dislocation, a small and shallow true acetabulum, abnormal femoral anteversion, a narrow femoral canal, soft-tissue contracture, limb shortening, abductor insufficiency and secondary osteoarthritis[2, 4, 5]. In symptomatic adults with advanced degeneration, THA is the definitive reconstructive option. However, the procedure is technically demanding and carries a higher risk of instability, nerve traction injury, osteotomy-related complications and revision than routine primary THA[3, 6].

Restoring the hip centre to the true acetabulum can improve biomechanics and limb length[7–9]. However, reducing a high-riding femur without shortening may excessively lengthen the limb and increase neurovascular tension[10–12]. Subtrochanteric femoral shortening osteotomy is therefore widely used in Crowe type IV DDH to facilitate reduction, correct femoral rotational deformity and permit stable femoral component fixation while limiting limb lengthening[13–15]. Transverse osteotomy is technically reproducible and preserves flexibility for rotational correction, although stable fixation and biological union remain essential[16, 17].

Previous studies have mainly focused on global clinical improvement and osteotomy union after THA with femoral shortening osteotomy. Less attention has been paid to factors associated with postoperative functional recovery, including acetabular component orientation and residual limb-length inequality. Because cup malposition may influence hip biomechanics, impingement, abductor efficiency, polyethylene wear and instability, we hypothesised that acetabular cup inclination would be associated with postoperative HHS in this complex population[18, 19].

This study evaluated the mid-term clinical, radiographic, complication and implant survival outcomes of THA combined with transverse subtrochanteric shortening osteotomy in Crowe type IV DDH. It also explored factors associated with postoperative functional recovery.

Materials and Methods

Study Design and Patients

This retrospective cohort study was approved by the Ethics Committee. Adult patients were eligible if they had Crowe type IV DDH, underwent THA combined with transverse subtrochanteric shortening osteotomy between 2014 and 2023, and had available clinical and radiographic follow-up. Patients were excluded if they had incomplete clinical or radiographic data, a follow-up period shorter than 2 years, bilateral DDH in which only one side underwent surgery during the study period, Charcot joint disease or

other neurological disorders. For excluded bilateral cases, the contralateral side had either been operated on previously or was not yet indicated for surgery.

A total of 46 patients (53 hips) met the study criteria. The cohort included 43 women and 3 men. Seven patients had bilateral involvement treated during the study period, and 39 had unilateral involvement. Baseline demographic characteristics are summarised in Table 1.

Surgical Technique

All operations were performed by experienced arthroplasty surgeons using a standardised institutional protocol for high-dislocation dysplastic hips. After induction of anaesthesia, the patient was placed in the lateral decubitus position. The skin was prepared three times with routine iodine tincture disinfection, sterile drapes were applied, and an iodophor adhesive film was placed over the operative field. A modified Hardinge approach was used through an approximately 15-cm incision. The subcutaneous tissue and tensor fasciae latae were dissected, and the anterior half of the gluteus medius was split in line with its fibres toward the vastus lateralis. The joint capsule was exposed and opened with a T-shaped capsulotomy, after which the hip was dislocated. Femoral neck osteotomy was then performed, and the femoral head was removed and preserved for later use. The true acetabulum was identified by following the elongated capsule. Soft tissue at the acetabular floor was removed, and the true acetabulum was initially reamed with the smallest available reamer, followed by stepwise enlargement. During reaming, the anterior and superior acetabular walls were inspected carefully. The acetabular reamer was used to remove surface cartilage until uniform cancellous bleeding was observed. After the acetabular floor had been reached, an acetabular trial component was inserted. Its stability was confirmed, and the acetabulum was irrigated repeatedly with normal saline.

An appropriately sized acetabular outer cup was then implanted at suitable abduction and anteversion angles, with host bone coverage of the cup exceeding 70%. After cup stability had been confirmed, two or three screws were inserted to augment fixation, and the liner was placed. The femoral canal was opened at the tip of the greater trochanter and sequentially broached to an appropriate size. Subtrochanteric osteotomy was then performed. The osteotomy length was determined according to intraoperative soft-tissue tension, the tightness of hip reduction and preoperative measurements. To facilitate subsequent end-to-end alignment, Kirschner wires were used to drill positioning holes as osteotomy markers. After osteotomy, the osteotomy ends were prebound with cerclage wires to prevent femoral splitting. The proximal and distal femoral segments were closely apposed with bone-holding forceps, the canal was re-reamed with broaches, and an appropriately sized trial prosthesis was selected. After thorough irrigation of the femoral canal and confirmation of appropriate hip tension, the femoral stem prosthesis and femoral head were implanted. After reduction, hip motion and surrounding soft-tissue tension were reassessed. C-arm fluoroscopy was used to confirm satisfactory component position. The wound was irrigated repeatedly with iodophor, active bleeding was controlled with electrocautery, a drainage tube was placed, and the wound was closed in layers followed by sterile dressing.

All hips were reconstructed with a cementless tapered titanium stem (Wagner-type cone stem; 41 hips) or a cementless cylindrical stem with a proximal sleeve (S-ROM; 12 hips), with supplemental cerclage-wire fixation at the osteotomy site (no additional plate was used), together with a cementless porous-coated acetabular component. Among the six revised hips, five had Wagner-type stems and one had an S-ROM stem. The small number of events precluded a formal comparison between implant types.

Clinical and Radiographic Evaluation

Clinical assessment included HHS, VAS pain score, LLD, use of assistive devices, presence of abductor lurch, operative time, length of hospital stay, transfusion, complications and revision. LLD was measured clinically using graduated blocks under the shorter limb with the patient standing. It was also measured radiographically on weight-bearing anteroposterior pelvic radiographs as the vertical distance between the line connecting the inferior margins of the teardrops and the corresponding lesser trochanter apices. LLD values entered the correlation and regression analyses were based on radiographic measurements, defined as the vertical distance from the inter-teardrop line to the apex of the lesser trochanter on weight-bearing anteroposterior pelvic radiographs. The clinical block method was used only for bedside assessment and was not included in the statistical models. Radiographic assessment included preoperative and postoperative femoral offset and acetabular offset, as well as postoperative cup inclination, cup anteversion and cup size[18, 20]. Cup inclination was measured on weight-bearing anteroposterior pelvic radiographs as the angle between the long axis of the elliptical cup opening and the inter-teardrop line. Cup anteversion was estimated from the same radiograph using the validated method described by Park et al.[20], in which anteversion is derived from the ratio of the minor to major axis of the projected elliptical cup opening. All radiographic measurements were obtained on standardised anteroposterior pelvic radiographs or available postoperative imaging by two independent trained observers. Inter-observer reliability was assessed using intraclass correlation coefficients (ICCs) for continuous variables and kappa statistics for categorical variables. ICC values > 0.75 were considered to indicate good reliability.

Statistical Analysis

Continuous variables are presented as the mean ± standard deviation or median with interquartile range, according to distribution. Categorical variables are presented as counts and percentages. Preoperative and postoperative paired outcomes were compared using paired tests as appropriate. Correlations between postoperative functional outcome and candidate radiographic or clinical variables were assessed using correlation analysis. Multivariable linear regression was performed to identify independent predictors of postoperative HHS. Receiver operating characteristic (ROC) analysis was used to evaluate discrimination for suboptimal functional recovery, defined as postoperative HHS < 80. Kaplan-Meier survival analysis was performed with revision as the endpoint. Because seven patients contributed both hips, the primary regression model was also re-estimated with patient-level cluster-robust standard errors (with patient as the clustering unit), and a sensitivity analysis restricted to one hip

per patient was performed. The primary multivariable linear regression model used postoperative HHS as the dependent variable, with cup inclination, cup anteversion, cup size, postoperative LLD, postoperative femoral offset and postoperative acetabular offset as predictors. A sensitivity analysis (Model 2) additionally included age, sex, BMI, follow-up duration and bilateral involvement; Model 2 was regarded as exploratory only and was not used for primary inference. Variables were entered simultaneously. Variance inflation factors (VIFs) were examined and all were < 2. For the one-hip-per-patient sensitivity analysis, the first-listed hip in the source database was retained for each bilateral patient, without reference to postoperative HHS, cup inclination, or any other outcome. All analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

Results

Patient Characteristics

The mean age was 50.3 ± 11.0 years, mean BMI was 24.4 ± 3.6 kg/m², and mean follow-up was 6.2 ± 1.8 years. Most patients were women (93.5%), and most had unilateral disease (84.8%).

Clinical Outcomes

Clinical outcomes improved substantially after surgery (Table 2). Mean HHS increased from 30.9 ± 7.8 preoperatively to 89.9 ± 6.7 postoperatively. Mean VAS decreased from 4.7 ± 1.1 to 1.4 ± 1.0. Median LLD improved from 52.0 mm preoperatively to 5.4 mm postoperatively. Independent ambulation increased from 36 of 46 patients (78.3%) to 45 of 46 patients (97.8%), and abductor lurch decreased from 32 patients (69.6%) to 5 patients (10.9%). The mean operative time was 148.8 ± 44.8 minutes, median hospital stay was 9 days, and 25 patients (54.3%) received transfusion.

Radiographic Outcomes

Radiographic results are summarised in Table 3. Femoral offset was maintained after surgery (31.8 ± 9.2 mm preoperatively versus 30.7 ± 6.4 mm postoperatively). Acetabular offset decreased from 23.6 ± 12.7 mm to 19.1 ± 6.9 mm. The mean postoperative cup inclination was 44.8 ± 10.7 degrees, mean cup anteversion was 14.6 ± 4.9 degrees, and mean cup size was 43.6 ± 3.0 mm. Inter-observer reliability was good for all continuous radiographic measurements, with ICC(2,1) values ranging from 0.801 to 0.916 (Table 8).

Complications and Survival

Major complications are listed in Table 4. There was one delayed union or nonunion event (2.2%), three dislocations (6.5%) and two cases of aseptic loosening (4.3%). No intraoperative femoral fracture, sciatic nerve palsy, deep venous thrombosis or infection was recorded. Six revisions occurred during follow-up.

Kaplan-Meier survival with revision as the endpoint was 95.7% at 1 year, 93.5% at 2 years, and 87.0% from 3 years through 10 years (95% CI, 77.2% to 96.7%) (Fig. 1).

Factors Associated with Functional Recovery

Cup inclination was negatively correlated with postoperative HHS (r = -0.42; approximate 95% CI, -0.62 to -0.17), indicating lower HHS with greater cup inclination (Fig. 2). Cup anteversion, cup size and postoperative residual LLD showed no meaningful correlations with postoperative HHS. ROC analysis demonstrated moderate discrimination of cup inclination for postoperative HHS < 80 (AUC = 0.758), with an optimal cutoff of approximately 55.13 degrees in this analysis (sensitivity 63.6%, specificity 92.9%) (Fig. 3). In contrast, postoperative residual LLD showed poor discrimination for HHS < 80 (AUC = 0.524) (Fig. 4). In a descriptive subgroup analysis, hips with cup inclination > 55 degrees (n = 10) had a lower mean postoperative HHS (81.7) than hips with inclination ≤ 55 degrees (n = 43; 91.2). However, dislocation and revision were not confined to high-inclination cups: only one of the three dislocations (57.4 degrees) and two of the six revisions had inclination > 55 degrees. In the primary multivariable model with patient-level cluster-robust inference (Table 5), cup inclination remained inversely associated with postoperative HHS (β = -0.359 per degree, cluster-robust SE = 0.094, 95% CI, -0.549 to -0.169; P = 0.0004). Cup size was also inversely associated with postoperative HHS (β = -0.641 per mm, cluster-robust SE = 0.290, 95% CI -1.225 to -0.057, P = 0.032). Cup anteversion, postoperative LLD, postoperative femoral offset and postoperative acetabular offset were not statistically significant. The primary model explained 25.6% of the variance in postoperative HHS (R^2 = 0.256; adjusted R^2 = 0.159), and the cluster-robust joint Wald test was significant (F(6, 45) = 5.05, P < 0.001). In Model 2, which additionally adjusted for age, sex, BMI, follow-up duration and bilateral involvement, cup inclination remained inversely associated with postoperative HHS (β = -0.309 per degree, cluster-robust SE = 0.116, 95% CI -0.542 to -0.076; P = 0.010). No other covariate was statistically significant in Model 2. This sensitivity model explained 32.0% of the variance (R^2 = 0.320; adjusted R^2 = 0.138), with a cluster-robust joint Wald F(11, 45) = 2.80 (P = 0.007). Cup inclination did not differ significantly between revised hips (n = 6; 48.5 ± 15.8 degrees) and non-revised hips (n = 47; 44.3 ± 10.0 degrees; P = 0.365). An era-stratified analysis, split at the median year of surgery, showed directionally consistent negative correlations between cup inclination and postoperative HHS in the early (r = -0.275) and late (r = -0.469) eras, although the smaller strata reduced statistical power. In the one-hip-per-patient sensitivity analysis (46 patients and 46 hips), cup inclination remained inversely associated with postoperative HHS (β = -0.346 per degree, SE = 0.095, 95% CI -0.539 to -0.153; P = 0.0008; Table 7). The model explained 26.8% of the variance (R^2 = 0.268; adjusted R^2 = 0.156), with F(6, 39) = 2.38 (P = 0.047).

Discussion

This study found that THA combined with transverse subtrochanteric shortening osteotomy produced substantial mid-term clinical improvement in patients with Crowe type IV DDH. The magnitude of HHS improvement, pain reduction, LLD correction and walking recovery was consistent with previous reports of THA and femoral shortening osteotomy for high-dislocation dysplastic hips[11, 13, 15, 21]. The 5- and

10-year Kaplan-Meier survival estimate of 87.0% indicates acceptable durability in a technically complex cohort, although revision risk remains clinically relevant.

The main additional finding was an inverse association between cup inclination and postoperative HHS after accounting for within-patient correlation. In the primary model, each 1-degree increase in cup inclination was associated with a 0.359-point decrease in postoperative HHS (cluster-robust P = 0.0004). This association persisted in the exploratory model with additional demographic adjustment. Patient-level clustering reduces concern arising from the inclusion of bilateral hips, but it does not eliminate residual confounding or establish causality. Cup size was associated with HHS only in the primary model and not in the model with additional demographic adjustment or in the one-hip-per-patient sensitivity analysis, further supporting cautious interpretation of individual coefficients. Cup inclination showed moderate discrimination for HHS < 80 (AUC = 0.758); however, the exploratory cutoff of 55.1 degrees was not externally validated and should not be interpreted as a universal treatment threshold. A mechanical relationship is plausible because excessive inclination may reduce superior coverage, alter joint reaction forces and increase edge loading[5, 18, 22, 23]. Nevertheless, confounding by indication is an important alternative explanation. A small or deficient true acetabulum may require surgeons to accept a more vertical cup to obtain adequate host-bone coverage, and the same anatomical severity may adversely affect functional recovery. The observed association may therefore reflect underlying anatomy and operative constraints rather than a direct effect of cup inclination on HHS. We regard this finding as hypothesis-generating rather than causal.

Residual LLD was markedly improved after reconstruction but did not correlate with postoperative HHS in this cohort. This finding should not be interpreted as evidence that LLD is clinically unimportant. Rather, it suggests that once LLD has been corrected to a generally small and tolerable residual range, other factors may become more important determinants of patient-reported function. These factors may include hip mechanics, abductor recovery, component orientation, soft-tissue balance and complication avoidance. The weak ROC performance of residual LLD also indicates that postoperative HHS < 80 cannot be explained by limb-length inequality alone.

Our results are consistent with recently published data on Crowe type IV DDH reconstruction. Lari et al. reported a multicentre series of 37 patients (49 hips) that showed significant improvements in functional scores and acceptable complication rates after THA with femoral shortening[16]. The present study extends these findings in several respects. Our cohort was larger, had longer follow-up, and identified an inverse association between cup inclination and postoperative functional outcome through multivariable modelling with patient-level cluster-robust inference. This association was not examined in the Lari series. The transfusion rate of 54.3% was clinically important. Although the study lacked a contemporaneous comparator, the high rate may reflect the prolonged operative time, extensive soft-tissue release, femoral osteotomy and technically demanding anatomy of Crowe type IV reconstruction. This finding underscores the importance of perioperative blood-conservation strategies. Furthermore, the dislocation rate in our study (6.5%) was comparable to the 5.4% reported by Lari et al., confirming that instability remains a persistent challenge in this complex population. The aseptic loosening rate

(4.3%) and osteotomy nonunion rate (2.2%) were also within the range of published benchmarks for Crowe type IV reconstruction[17, 24].

The complication profile was within the range expected for Crowe type IV DDH reconstruction. Dislocation remains a notable risk because of altered soft-tissue tension, abnormal anatomy, prior adaptive gait and the complexity of reducing a high-riding femur into the anatomical acetabulum[25]. Osteotomy healing was generally reliable, with only one delayed union or nonunion event recorded. No sciatic nerve palsy occurred, supporting the protective role of femoral shortening when limb lengthening and reduction tension are carefully controlled[12].

The use of transverse subtrochanteric shortening osteotomy also deserves specific consideration. In this series, transverse osteotomy was selected because it is technically reproducible, allows rotational correction after femoral preparation and can facilitate reduction while limiting excessive limb lengthening[26–28]. Compared with more geometrically complex osteotomy configurations, its simplicity may shorten the learning curve and make intraoperative adjustment more straightforward. However, rotational stability depends on secure stem fixation, close apposition of the osteotomy surfaces and supplemental cerclage fixation[21, 29]. The low rate of delayed union or nonunion in this cohort supports the feasibility of this approach, but the present study was not designed to compare transverse osteotomy with step-cut, oblique or other osteotomy techniques.

This study has several limitations. First, this was a retrospective single-institution study without a comparison group of non-dysplastic THA or non-osteotomy reconstructions. Therefore, the complication and functional profiles therefore cannot be attributed specifically to the osteotomy technique. Second, seven patients contributed bilateral hips. We used patient-level cluster-robust variance estimates, but the small number of bilateral cases limits precise characterisation of within-patient correlation. The sample size also limited power to detect smaller effects and precluded reliable interaction testing. Model 2 included 11 predictors for 53 hips and was vulnerable to overfitting; it was therefore treated only as an exploratory sensitivity analysis and not used for primary inference. The regression findings require external validation in larger prospective cohorts[30]. Third, the 2014–2023 enrolment window and 3.2-12.3-year follow-up range allow for changes in technique and implant selection over time. In an era-stratified sensitivity analysis using 2020 as the cutoff, the association between cup inclination and HHS remained directionally negative in both eras. The small strata and limited number of outcome events, however, mean that this analysis cannot exclude residual era-related confounding. Fourth, HHS < 80 was an exploratory threshold that has not been validated in this population; the ROC findings should therefore be interpreted descriptively rather than as a clinical decision rule. Fifth, the dataset did not capture all potentially important determinants of function, including spinopelvic mobility, abductor muscle quality, bearing surface, rehabilitation adherence and patient-reported outcomes beyond HHS and VAS. Accordingly, the association between cup inclination and HHS is hypothesis-generating and should not be interpreted as proof of causality.

Despite these limitations, the findings support meticulous acetabular component positioning during THA for Crowe type IV DDH. They do not justify a universal inclination cutoff or establish that changing inclination will improve HHS. In addition to achieving reduction, osteotomy stability and limb-length correction, avoiding clearly excessive inclination may be prudent. They should also evaluate whether intraoperative cup orientation is likely to restore stable biomechanics in the context of each patient's dysplastic anatomy.

Conclusions

THA combined with transverse subtrochanteric shortening osteotomy achieved substantial mid-term improvements in function, pain, gait and limb-length discrepancy in patients with Crowe type IV DDH. Implant survival and major complications were acceptable. After accounting for bilateral observations, greater cup inclination remained inversely associated with postoperative HHS, but the models explained only a modest proportion of outcome variability and residual confounding remains likely. Cup size was associated with HHS only in the primary model, whereas cup anteversion and postoperative LLD were not statistically significant. The findings therefore do not establish that cup inclination determines HHS or that modifying inclination would improve recovery. In an exploratory ROC analysis, cup inclination showed moderate discrimination with respect to HHS < 80 (AUC = 0.758); however, this result should be regarded as descriptive and not as evidence supporting a clinical decision threshold. Although the effect size was modest and requires prospective confirmation, attention to acetabular component orientation may be prudent in this demanding reconstruction. Given the relative rarity of Crowe type IV DDH, this single-centre cohort provides a useful basis for interpreting factors associated with recovery. Larger studies with longer follow-up are needed to validate these findings.

Declarations

Ethical Statement

This study was approved by the Ethics Committee. The requirement for informed consent was waived by the committee due to the retrospective nature of the study and the use of anonymized patient data. All data were analyzed anonymously, and no identifiable personal information is included in this manuscript. The research was carried out in compliance with the ethical principles outlined in the Declaration of Helsinki.

Author Contribution

Y.X. conducted the investigation, curated the data, performed the formal analysis, and wrote the original draft. W.M. and J.B. participated in the investigation and data curation, and contributed to the review and editing of the manuscript. L.Y. participated in the investigation and contributed to the review and editing of the manuscript. Y.Z. and G.W. were responsible for conceptualization, methodology, and supervision,

and contributed to the review and editing of the manuscript. All authors reviewed and approved the final manuscript.

Acknowledgements

The authors declare that no funding, grants, or other financial support was received from any public, commercial, or not-for-profit organization for the conduct of this study or the preparation of this manuscript.

References

1. Crowe JF, Mani VJ, Ranawat CS. Total hip replacement in congenital dislocation and dysplasia of the hip. J Bone Joint Surg Am. 1979;61(1):15–23.
2. Argenson JNA, Flecher X, Parratte S, Aubaniac JM. Anatomy of the dysplastic hip and consequences for total hip arthroplasty. Clin Orthop Relat Res. 2007;465:40–5. 10.1097/BLO.0b013e3181576052.
3. Greber EM, Pelt CE, Gililland JM, Anderson MB, Erickson JA, Peters CL. Challenges in total hip arthroplasty in the setting of developmental dysplasia of the hip. J Arthroplasty. 2017;32(9S):S38–44. 10.1016/j.arth.2017.02.024.
4. Yang Y, Liao W, Yi W, et al. Three-dimensional morphological study of the proximal femur in crowe type IV developmental dysplasia of the hip. J Orthop Surg Res. 2021;16(1):621. 10.1186/s13018-021-02789-5.
5. Qian H, Wang X, Wang P, et al. Total hip arthroplasty in patients with crowe III/IV developmental dysplasia of the hip: Acetabular morphology and reconstruction techniques. Orthop Surg. 2023;15(6):1468–76. 10.1111/os.13733.
6. Poursalehian M, Hassanzadeh A, Shafiei SH, Mortazavi SMJ. Mid- to long-term outcomes and complications of total hip arthroplasty in patients who have crowe IV developmental dysplasia of the hip: A systematic review and meta-analysis. J Arthroplast. 2025;40(2):530–9. 10.1016/j.arth.2024.08.026.
7. Krych AJ, Howard JL, Trousdale RT, Cabanela ME, Berry DJ. Total hip arthroplasty with shortening subtrochanteric osteotomy in crowe type-IV developmental dysplasia. J Bone Joint Surg Am. 2009;91(9):2213–21. 10.2106/JBJS.H.01024.
8. Suzuki M, Masuda T, Kanno T, Inoue M, Abe S, Yamamoto T. Minimum 10-year survivorship of uncemented acetabular reconstruction with bulk femoral head autografting in crowe type IV developmental hip dysplasia. J Arthroplasty. 2024;39(10):2542–6. 10.1016/j.arth.2024.05.013.
9. Zeng WN, Liu JL, Wang FY, et al. Total hip arthroplasty for patients with crowe type IV developmental dysplasia of the hip: Ten years results. Int J Surg. 2017;42:17–21. 10.1016/j.ijsu.2017.04.029.

10. Meng J, Hu B, Yan S, Liu A, Wu H. Comparison of cementless total hip arthroplasty with or without subtrochanteric shortening osteotomy in crowe type IV developmental dysplasia of the hip. J Arthroplasty Published online August 25, 2025:S0883-5403(25)01092-7. 10.1016/j.arth.2025.08.051
11. Akbulut D, Akgün H, Coşkun M. Comparison of outcomes in total hip arthroplasty for unilateral crowe type IV hip dislocation with and without femoral shortening osteotomy: Determining factors for shortening. J Arthroplasty. 2026;41(5):1473–81. 10.1016/j.arth.2025.09.030.
12. El-Ganzoury I, Ghazavi MT, Özden VE, et al. Is there a limit to lengthening in patients who have crowe IV developmental dysplasia of the hip undergoing total hip arthroplasty? J Arthroplasty. 2025;40(2S1):S132–5. 10.1016/j.arth.2024.10.079.
13. Lu Z, Chen Q, Lan Y, Xie S, Lin F, Feng E. Subtrochanteric osteotomy in direct anterior approach total hip arthroplasty for crowe IV dysplasia-surgical technique and literature review. Orthop Surg. 2024;16(3):766–74. 10.1111/os.13996.
14. Shen X, Zhang R, Mei J, Zhang X, Huang W, Zhu C. Total hip arthroplasty combined with proximal femoral reconstruction effectively treats severe hip deformities: A novel osteotomy technique. Orthop Surg. 2024;16(8):1939–45. 10.1111/os.14136.
15. Dai Y, Luo Z, Li G, Chen M, Zhu C, Shang X. Direct anterior approach combined with proximal femoral osteotomy for crowe type IV developmental dysplasia in total hip arthroplasty. J Arthroplasty. 2026;41(2):501–7. 10.1016/j.arth.2025.06.073.
16. Lari A, Ayyad SH, Khan T, Alemairi T, El-Bakoury A, Hammad AS. Outcomes and complications of total hip arthroplasty for crowe type IV dysplasia of the hip: An international multicenter study. J Arthroplasty Published online November. 2025;17(25):S0883–5403. 10.1016/j.arth.2025.11.012.
17. Li C, Zhang C, Zhang M, Ding Y. Comparison of transverse and modified subtrochanteric femoral shortening osteotomy in total hip arthroplasty for developmental dysplasia of hip: A meta-analysis. BMC Musculoskelet Disord. 2014;15:331. 10.1186/1471-2474-15-331.
18. Bicanic G, Delimar D, Delimar M, Pecina M. Influence of the acetabular cup position on hip load during arthroplasty in hip dysplasia. Int Orthop. 2009;33(2):397–402. 10.1007/s00264-008-0683-z.
19. Lewinnek GE, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am. 1978;60(2):217–20.
20. Park YS, Shin WC, Lee SM, Kwak SH, Bae JY, Suh KT. The best method for evaluating anteversion of the acetabular component after total hip arthroplasty on plain radiographs. J Orthop Surg Res. 2018;13(1):66. 10.1186/s13018-018-0767-4.
21. Mimendia I, Lakhani K, Núñez JH, et al. Total hip arthroplasty associated with transverse subtrochanteric shortening osteotomy and conical stem fixation in crowe type IV hip dysplasia. Musculoskelet Surg. 2023;107(3):367–72. 10.1007/s12306-023-00779-w.
22. Pagnano W, Hanssen AD, Lewallen DG, Shaughnessy WJ. The effect of superior placement of the acetabular component on the rate of loosening after total hip arthroplasty. J Bone Joint Surg Am. 1996;78(7):1004–14. 10.2106/00004623-199607000-00004.

23. Georgiades G, Babis GC, Kourlaba G, Hartofilakidis G. Effect of cementless acetabular component orientation, position, and containment in total hip arthroplasty for congenital hip disease. J Arthroplasty. 2010;25(7):1143–50. 10.1016/j.arth.2009.12.016.
24. Esmaeili S, Ghaseminejad-Raeini A, Ghane G, Soleimani M, Mortazavi SMJ, Shafiei SH. Total hip arthroplasty in patients who have crowe type IV developmental dysplasia of the hip: A systematic review. J Arthroplasty. 2024;39(10):2645–e266019. 10.1016/j.arth.2024.05.031.
25. Ding ZC, Zeng WN, Mou P, Liang ZM, Wang D, Zhou ZK. Risk of dislocation after total hip arthroplasty in patients with crowe type IV developmental dysplasia of the hip. Orthop Surg. 2020;12(2):589–600. 10.1111/os.12665.
26. Caylak R, Ors C, Togrul E. Minimum 10-year results of cementless ceramic-on-ceramic total hip arthroplasty performed with transverse subtrochanteric osteotomy in crowe type IV hips. J Arthroplasty. 2021;36(10):3519–26. 10.1016/j.arth.2021.05.035.
27. Sofu H, Kockara N, Gursu S, Issin A, Oner A, Sahin V. Transverse subtrochanteric shortening osteotomy during cementless total hip arthroplasty in crowe type-III or IV developmental dysplasia. J Arthroplasty. 2015;30(6):1019–23. 10.1016/j.arth.2015.01.045.
28. Masonis JL, Patel JV, Miu A, et al. Subtrochanteric shortening and derotational osteotomy in primary total hip arthroplasty for patients with severe hip dysplasia: 5-year follow-up. J Arthroplasty. 2003;18(3 Suppl 1):68–73. 10.1054/arth.2003.50104.
29. Muratli KS, Karatosun V, Uzun B, Celik S. Subtrochanteric shortening in total hip arthroplasty: Biomechanical comparison of four techniques. J Arthroplasty. 2014;29(4):836–42. 10.1016/j.arth.2013.09.004.
30. Poursalehian M, Hassanzadeh A, Shafiei SH, Mortazavi SMJ. Mid- to long-term outcomes and complications of total hip arthroplasty in patients who have crowe IV developmental dysplasia of the hip: A systematic review and meta-analysis. J Arthroplasty. 2025;40(2):530–9. 10.1016/j.arth.2024.08.026.

Tables

Table 1. Patient demographics.

	All Cases
	N=46 (53 hips)
Follow-up (Years)(SD)	6.20 (1.82)
Age(SD)	50.30 (10.96)
Height (cm)(SD)	156.91 (5.53)
Weight (kg)(SD)	60.00 (9.17)
BMI (kg/m^2)(SD)	24.38 (3.58)
Sex: (%)	
Women	43 (93.5)
Men	3 (6.5)
Affected Side: (%)	
Bilateral	7 (15.2)
Unilateral	39 (84.8)

Abbreviations BMI, body mass index.

Table 2. Preoperative and postoperative clinical results.

Variable	Pre-operative	Post-operative	Change Mean[95% CI]	P-Value
	N=46			
LLD (mm)	52.02[25.73;66.99]	5.47 [2.69;12.55]	-39.20[-46.53, -31.87]	< 0.001
HHS	30.9 (7.8)	89.93 (6.71)	59.04 [56.07, 62.02]	< 0.001
VAS	4.7 (1.1)	1.35 (0.97)	-3.33 [-3.72, -2.94]	< 0.001
Ambulation				
Assistive devices	10 (21.7%)	1 (2.2%)		
Independent	36 (78.3%)	45 (97.8%)		0.008
Abductor lurch	32 (69.6%)	5 (10.9%)		< 0.001
Operative time (min)		148.8 (44.8)		
Hospital stay (days)		9.00 [7.00;11.00]		
Blood transfusion		25 (54.3%)		

Pre-operative LLD, HHS, and VAS values were compared to post-operative values using paired t-tests;results are reported as mean change with 95% confidence intervals and corresponding P-values. Changes in ambulation and abductor lurch status were evaluated using McNemar's test.

Abbreviations LLD, leg length discrepancy;HHS, Harris hip scores; VAS, Visual Analog Scale.

Table 3. Preoperative and postoperative radiographic results.

Variable	Preoperative	Postoperative	Change Mean[95% CI]	P-value
	N=53			
Radiographic outcomes				
Femoral offset (mm)	31.78 ± 9.17	30.72 ± 6.38	-1.06 [-4.22 to 2.10]	0.505
Acetabular offset (mm)	23.62 ± 12.66	19.09 ± 6.92	-4.53 [-7.73 to -1.32]	0.006
Postoperative component position				
Cup inclination (degree)		44.77 ± 10.66		
Cup anteversion (degree)		14.60 ± 4.90		
Cup size		43.60 ± 2.96		

Abbreviations FO, femoral offset; AO, acetabular offset.

Table 4. Major complications.

Complications	All patients (N=46)
Delayed union or nonunion	1 (2.2%)
Dislocation	3 (6.5%)
Intraoperative femoral fracture	0 (0.0%)
Sciatic nerve palsy	0 (0.0%)
Aseptic loosening	2 (4.3%)
Deep venous thrombosis	0 (0.0%)
Infection	0 (0.0%)

Table 5. Multivariable linear regression of factors associated with postoperative Harris Hip Score (primary model).

Variable	β	95% CI	SE	t	P-value
Cup inclination (°)	-0.359	-0.549, -0.169	0.094	-3.81	0.0004
Cup anteversion (°)	0.361	-0.097, 0.818	0.227	1.59	0.119
Cup size (mm)	-0.641	-1.225, -0.057	0.290	-2.21	0.032
Postoperative LLD (mm)	-0.059	-0.344, 0.226	0.142	-0.42	0.679
Postoperative FO (mm)	0.061	-0.217, 0.340	0.138	0.44	0.660
Postoperative AO (mm)	0.152	-0.093, 0.397	0.122	1.25	0.218

$R^2 = 0.256$, adjusted $R^2 = 0.159$; cluster-robust joint Wald $F(6, 45) = 5.05$, $P < 0.001$.

All variance inflation factors < 1.4.

Abbreviations: HHS, Harris Hip Score; LLD, leg-length discrepancy; FO, femoral offset; AO, acetabular offset; CI, confidence interval; SE, patient-level cluster-robust standard error. Estimates are based on 53 hips clustered within 46 patients.

Table 6. Sensitivity analysis: multivariable regression with additional adjustment for patient demographics (Model 2).

Variable	β	95% CI	SE	t	P-value
Cup inclination (°)	-0.309	-0.542, -0.076	0.116	-2.67	0.010
Age (years)	-0.003	-0.234, 0.227	0.114	-0.03	0.977
Male sex	-5.025	-15.868, 5.819	5.384	-0.93	0.356
BMI (kg/m²)	-0.415	-1.172, 0.342	0.376	-1.10	0.275
Follow-up (years)	0.403	-0.527, 1.333	0.462	0.87	0.387
Bilateral DDH	-2.228	-9.819, 5.363	3.769	-0.59	0.557
Cup anteversion (°)	0.311	-0.056, 0.678	0.182	1.71	0.095
Cup size (mm)	-0.420	-1.080, 0.239	0.328	-1.28	0.206
Postoperative LLD (mm)	-0.077	-0.369, 0.215	0.145	-0.53	0.598
Postoperative FO (mm)	0.102	-0.235, 0.439	0.167	0.61	0.546
Postoperative AO (mm)	0.234	-0.044, 0.513	0.138	1.69	0.097

$R^2 = 0.320$, adjusted $R^2 = 0.138$; cluster-robust joint Wald $F(11, 45) = 2.80$, $P = 0.007$.

The model additionally adjusted for age, sex, BMI, follow-up duration, and bilateral involvement.

All variance inflation factors < 2.0.

Abbreviations: HHS, Harris Hip Score; LLD, leg-length discrepancy; FO, femoral offset; AO, acetabular offset; BMI, body mass index; CI, confidence interval; SE, patient-level cluster-robust standard error. Estimates are based on 53 hips clustered within 46 patients.

Table 7. One-hip-per-patient sensitivity analysis of factors associated with postoperative Harris Hip Score.

Variable	β	95% CI	SE	t	P-value
Cup inclination (°)	-0.346	-0.539, -0.153	0.095	-3.63	0.0008
Cup anteversion (°)	0.323	-0.100, 0.745	0.209	1.55	0.130
Cup size (mm)	-0.611	-1.280, 0.057	0.331	-1.85	0.072
Postoperative LLD (mm)	-0.037	-0.314, 0.240	0.137	-0.27	0.789
Postoperative FO (mm)	0.053	-0.236, 0.341	0.143	0.37	0.714
Postoperative AO (mm)	0.120	-0.168, 0.407	0.142	0.84	0.405

$R^2 = 0.268$, adjusted $R^2 = 0.156$; $F(6, 39) = 2.38$, $P = 0.047$.

For each of the seven patients with bilateral hips, the first-listed hip in the source database was retained without reference to postoperative HHS, cup inclination, or any other outcome.

Abbreviations: HHS, Harris Hip Score; LLD, leg-length discrepancy; FO, femoral offset; AO, acetabular offset; CI, confidence interval; SE, conventional standard error. Estimates are based on 46 patients and 46 hips.

Table 8. Inter-observer reliability of radiographic measurements.

Radiographic measurement	ICC(2,1)	Interpretation
Preoperative LLD	0.916	Good
Postoperative LLD	0.859	Good
Preoperative FO	0.849	Good
Postoperative FO	0.899	Good
Preoperative AO	0.880	Good
Postoperative AO	0.801	Good
Cup inclination	0.889	Good
Cup anteversion	0.807	Good

ICC(2,1) denotes a two-way random-effects, absolute-agreement, single-measure intraclass correlation coefficient. ICC values > 0.75 were considered to indicate good reliability. Measurements were assessed independently by two trained observers in 53 hips.

Abbreviations: ICC, intraclass correlation coefficient; LLD, leg-length discrepancy; FO, femoral offset; AO, acetabular offset.

Figures

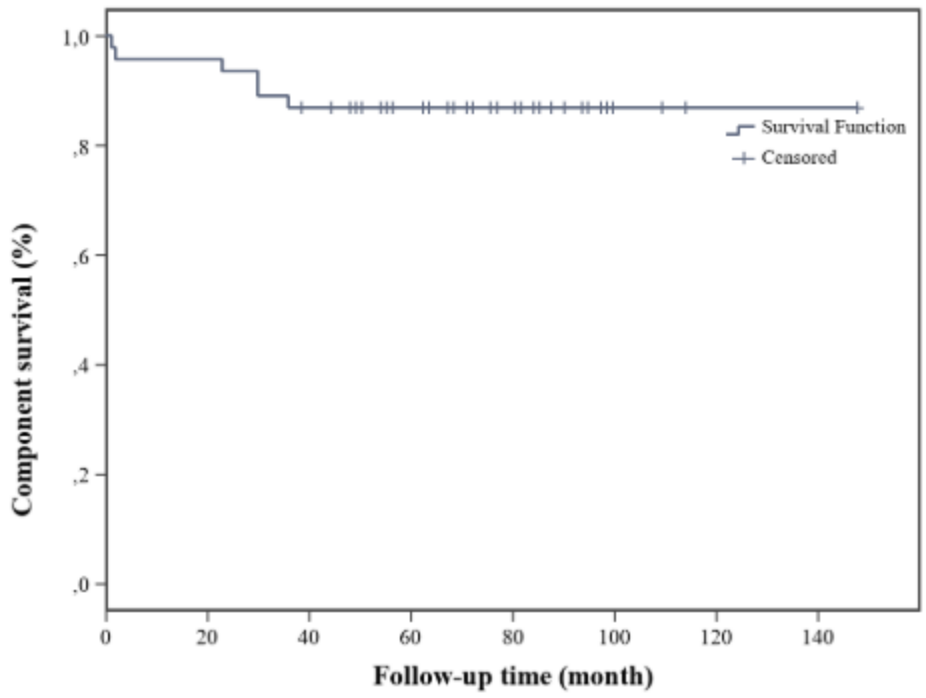


Figure 1

Kaplan-Meier survival analysis with revision as the endpoint.

Kaplan-Meier survivorship curve with revision for any reason as the endpoint. Dashed lines represent 95% confidence intervals. Survival was 87.0% at 5 and 10 years.

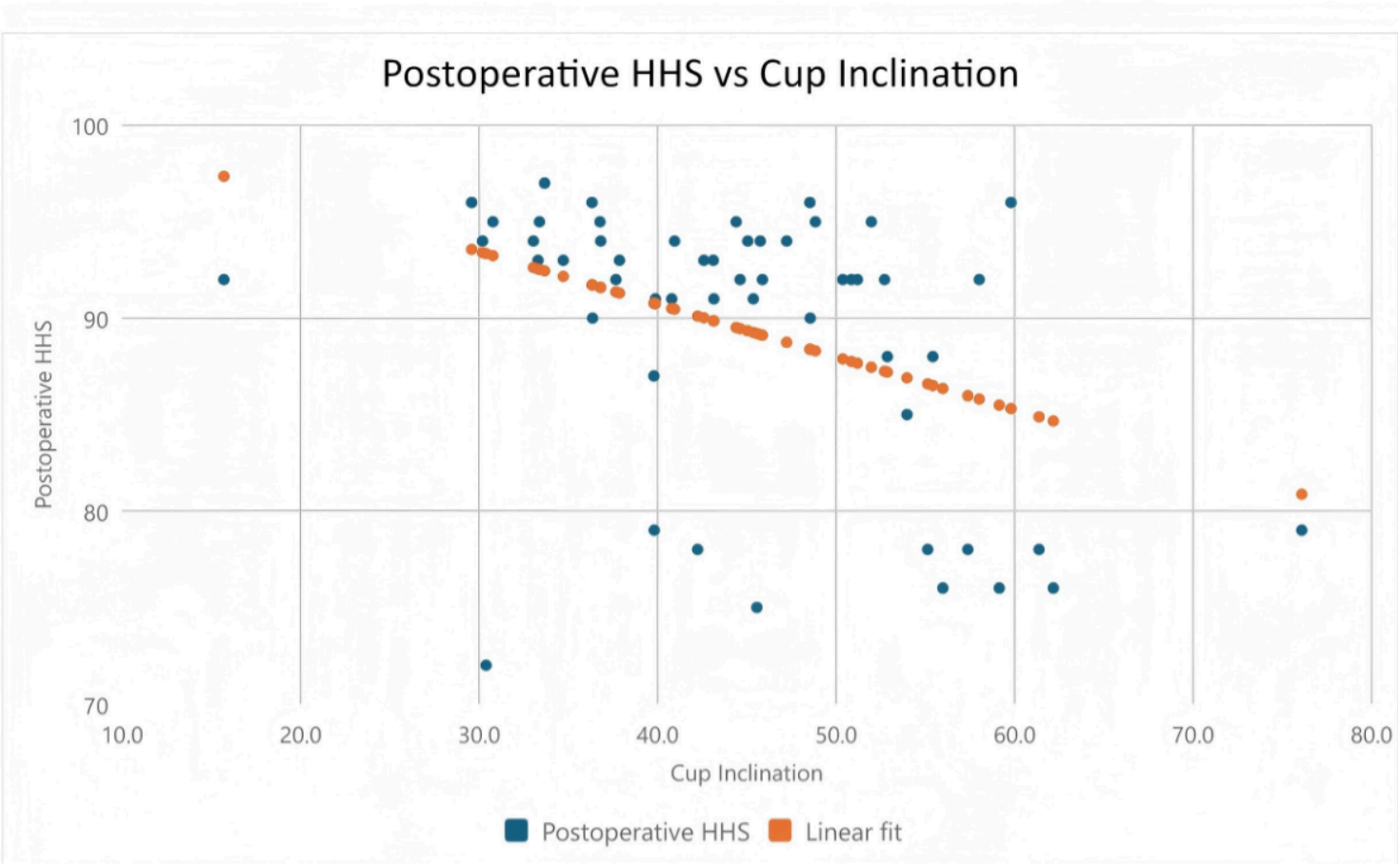


Figure 2

Correlation between postoperative HHS and cup inclination.

Scatter plot with linear regression line and 95% confidence band showing the negative correlation between postoperative cup inclination and postoperative HHS (r = -0.42, P = 0.002).

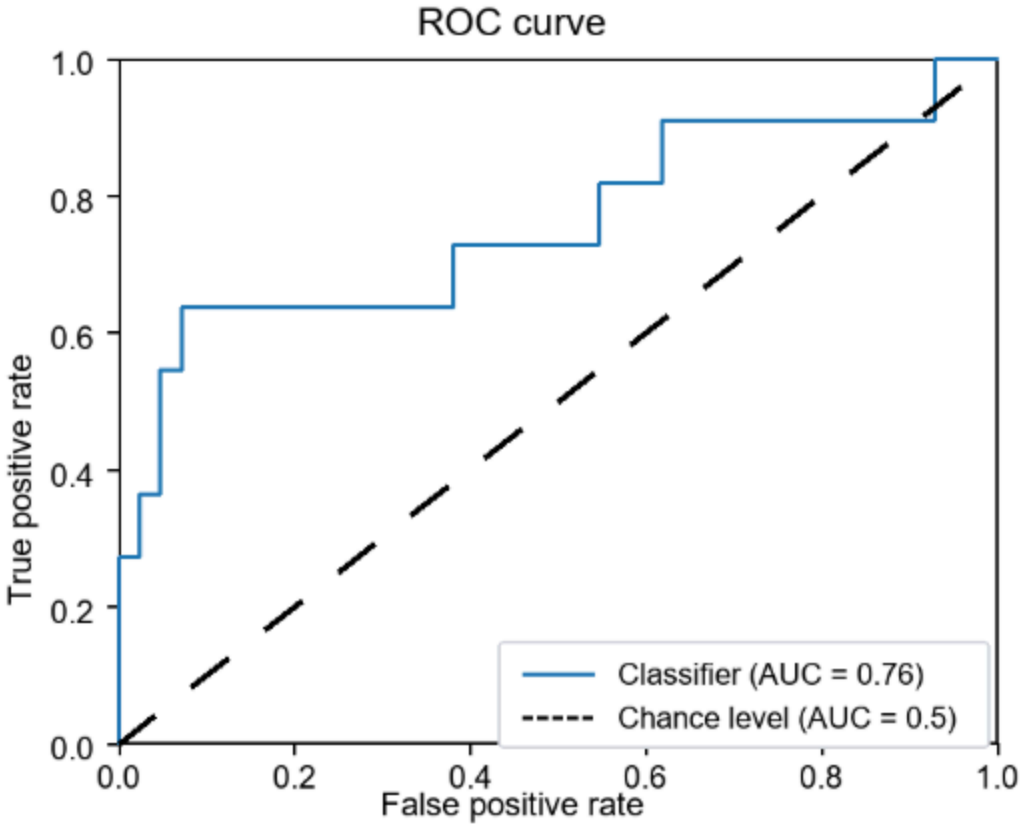


Figure 3

ROC curve for cup inclination predicting postoperative HHS < 80.

Receiver operating characteristic curve for cup inclination predicting suboptimal functional outcome (HHS < 80). AUC = 0.758. The optimal cutoff of 55.1 degrees yielded a sensitivity of 64% and specificity of 93%.

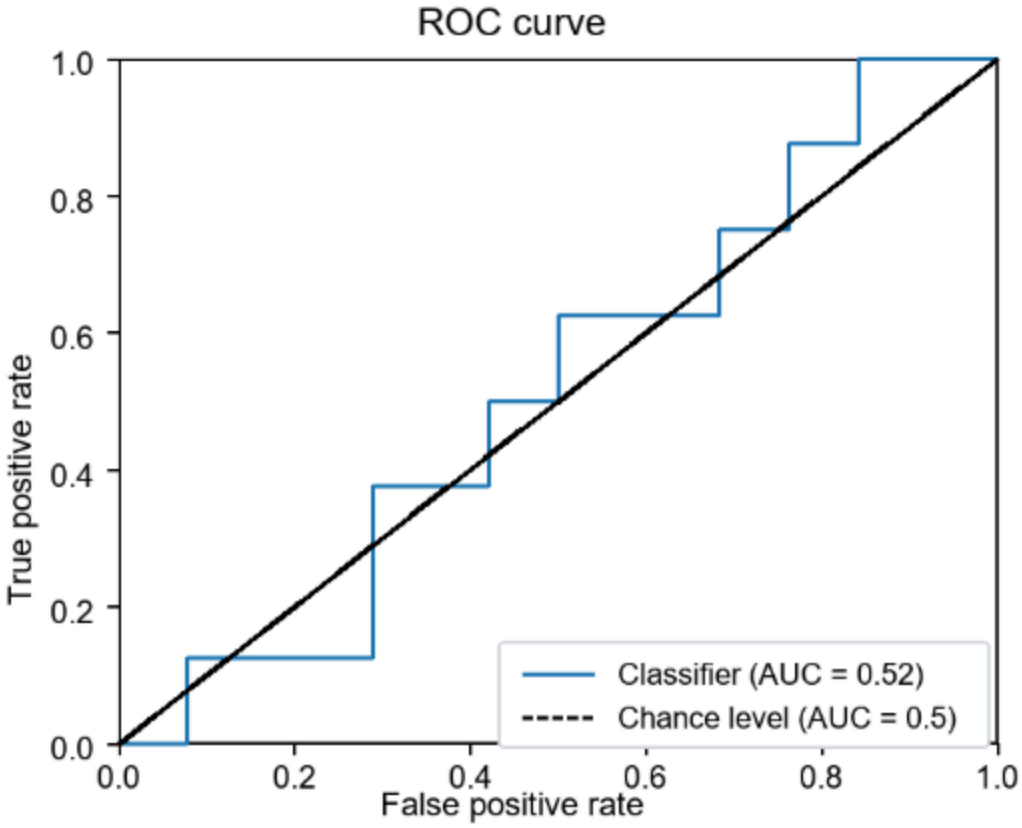


Figure 4

ROC curve for postoperative LLD predicting postoperative HHS < 80.

Receiver operating characteristic curve for postoperative LLD predicting suboptimal functional outcome (HHS < 80). AUC = 0.524, indicating poor discriminatory ability.