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Research Article

Lower extremity and spinopelvic alignment changes after total hip arthroplasty in unilateral Crowe III-IV dysplasia: clinical and radiological outcomes

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ABSTRACT

Objective: This study aimed to evaluate the short-term clinical and radiological outcomes of lower extremity and spinal changes following total hip arthroplasty (THA) in patients with unilateral Crowe type III and IV hip dysplasia.

Methods: This prospective study included patients who have Crowe type III and IV hip dysplasia evaluated at a high-volume arthroplasty center. Demographic and surgical characteristics were documented. Clinical assessments included the Harris Hip Score (HHS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Short Form-12 (SF-12), Kujala Score, Oxford Knee Score, Oswestry Disability Index (ODI), Roland-Morris Questionnaire, American Orthopedic Foot and Ankle Society (AOFAS) Score, and Foot and Ankle Disability Index (FADI). Radiological assessments included standing anteroposterior (AP) pelvis, AP leg length, and standing/seated lumbosacral AP and lateral radiographs preoperatively and at 1-year postoperatively.

Results: Thirty-three patients (mean age 52.7 ± 11.8 years) were followed for an average of 18.3 ± 7.0 months. Significant improvements were observed postoperatively in HHS and WOMAC scores for both ipsilateral and contralateral hips, SF-12, ODI, Roland-Morris, and ipsilateral knee WOMAC scores (all $P<0.05$). Radiologically, postoperative improvements included a significant reduction in leg length discrepancy ($P<0.001$), medial mechanical axis deviation on the ipsilateral side ($P<0.001$), increased joint line convergence angle and ankle joint line orientation, and spinopelvic alingment with increased sacral slope ($P=0.027$) and decreased lumbar lordotic angle ($P<0.001$).

Conclusion: Unilateral high-grade hip dysplasia, when treated with total hip arthroplasty (THA), results in significant short-term improvements in clinical outcomes and lower extremity alignment. In patients with an average follow-up duration of 18.3 ± 7.0 months, although the valgus deformity on the operated side improved, neutral alignment was not achieved. The contralateral limb remained in varus alignment. While spinopelvic parameters remained within normal limits, significant changes were observed in sacral slope and lumbar lordosis.

Level of Evidence: Level IV, Therapeutic Study.

Introduction

Developmental dysplasia of the hip (DDH) encompasses a wide anatomical spectrum ranging from acetabular deficiency to complete femoral head dislocation, disrupting hip biomechanics and leading to multisegmental alignment problems such as gait disturbance, lumbar pain, increased lordosis, genu valgum, and limb-length discrepancy.[1-4] Developmental dysplasia of the hip affects both axial and appendicular skeletal alignment, resulting in notable alterations in spinopelvic parameters and lower-limb mechanical axes.[5]

Developmental dysplasia of the hip is a major etiological factor for hip osteoarthritis and valgus deformity of the knee, frequently progressing to a stage requiring total hip arthroplasty (THA).[6-10] However, high-grade deformities such as Crowe types III-IV pose substantial technical challenges, for which cementless THA combined with femoral shortening osteotomy is commonly preferred to reduce neural traction and restore anatomical alignment.[11-13]

Genu valgum in DDH may be associated with developmental changes including femoral condyle hypoplasia and valgus-oriented tibial plateau morphology.[2,14] In Crowe type III-IV patients with normal preoperative knee alignment, early postoperative valgus increase has been attributed to limb lengthening and restoration of the anatomical hip center.[15,16] Conversely, studies achieving accurate femoral offset (FO) and hip reconstruction have reported improvements in knee and ankle valgus following THA.[4,17]

Beyond the hip and knee, THA in patients with DDH may also influence spinopelvic balance. Abnormal femoral head position can alter pelvic tilt (PT) and sagittal alignment, leading to compensatory spinopelvic adaptations. In unilateral DDH, limb-length discrepancy may result in pelvic obliquity (PO) and functional scoliosis, while posterior displacement of the femoral head has been associated with increased sacral slope (SS) and lumbar lordosis.[18-21] However, the effect of THA on spinopelvic parameters remains controversial. Some studies have reported postoperative

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improvements in pelvic alignment,[22,23] whereas others found minimal or no radiographic changes.[24,25] In particular, Morimoto et al[26] demonstrated increased SS and decreased lumbar lordosis after true-acetabular reconstruction in Crowe IV hips.

Previous research has largely concentrated on the effects of THA on the hip and knee joints, while its potential impact on more distal parts of the lower-limb kinetic chain—particularly the ankle and foot—has received limited attention. Changes in lower extremity alignment following THA may modify load transfer not only across the knee but also at the ankle joint, potentially resulting in secondary biomechanical adaptations. Nevertheless, studies evaluating radiographic ankle alignment and clinical outcomes at the foot–ankle level in patients with high-grade DDH remain scarce. Accordingly, the present study was designed to perform a comprehensive assessment of lower-extremity and spinopelvic alignment, including ankle alignment and foot–ankle clinical outcomes, in patients with unilateral Crowe type III and IV DDH treated with THA.

It was hypothesized that in patients who have unilateral Crowe type III and type IV hip dysplasia, restoring the hip to its anatomical position will lead to improvements in spinopelvic parameters and lumbar clinical scores, as well as clinical and radiological recovery not only in the hip but also in the knee and ankle joints.

Material and methods

This prospective study was conducted at a high-volume arthroplasty center and included patients diagnosed with unilateral Crowe type III and IV hip dysplasia. Ethical approval was obtained from Bezmialem Vakıf University (Approval No: E.16313; May 17, 2021)., and the trial was registered on ClinicalTrials.gov (NCT0617661). Consecutive patient enrollment was performed between May 2021 and December 2022 according to predefined inclusion and exclusion criteria. Radiological and clinical data were collected preoperatively and at the 1-year postoperative follow-up. Although the mean follow-up duration was 18.27 months, only the 12-month postoperative clinical and radiological outcomes were presented, as longer-term data were not available for most patients.

All patients were thoroughly informed about the surgical procedure, potential risks, and complications before the operation. Written informed consent was obtained from each participant.

In the postoperative period, patients who underwent an osteotomy were mobilized on the first day without weight-bearing. In cases where no osteotomy was performed, immediate full weight-bearing ambulation was permitted with the assistance of crutches or a walker. Quadriceps-strengthening exercises were demonstrated at the bedside to promote early muscle activation. At approximately 6 weeks postoperatively, progression to full weight-bearing was allowed based on the patient's clinical assessment and radiographic evidence of osteotomy union. During toileting and other activities of daily living, patients were instructed to maintain hip flexion below 90° and to avoid hip adduction in order to minimize stress on the operative site.

HIGHLIGHTS

- This study is the first comprehensive evaluation of hip–spine–knee–ankle alignment and spinopelvic parameters after total hip arthroplasty in patients who have unilateral Crowe III-IV developmental dysplasia of the hip (DDH).
- Total hip arthroplasty resulted in significant improvements in hip function, lumbar disability scores, and overall quality of life.
- Anatomical hip reconstruction achieved substantial correction of mechanical axis deviation and limb-length discrepancy.
- Significant postoperative changes were observed in sacral slope and lumbar lordosis, whereas improvements in knee and ankle alignment were limited.
- Despite successful restoration of proximal biomechanics, distal compensatory malalignment may persist, underscoring the importance of multi-joint assessment and long-term follow-up in high-grade DDH patients.

Demographic data and surgical characteristics

Preoperative assessment included a detailed medical history and physical examination. Demographic and clinical data such as age, sex, side of surgery, height, weight, body mass index, date of surgery, and date of the last follow-up were recorded for all patients. For those who underwent osteotomy, the occurrence and timing of bone union were also documented.

Intraoperative data were collected from operative reports and included the surgical approach, type and size of the acetabular cup (cemented or cementless), type of insert (neutral or offset), type and size of the femoral stem, femoral head size, and material type. Additionally, whether a femoral shortening procedure was performed was recorded, along with the amount of shortening measured in centimeters. Implant selection was individualized according to patient-specific anatomical features and deformity severity in high-grade DDH. All components shared comparable biomechanical design principles and fixation strategies, with reconstruction aimed at restoring the anatomical hip center; therefore, implant variability was not considered a confounding factor for clinical or radiological outcomes.

Clinical outcomes

Outcome measures were recorded preoperatively and at 12 months postoperatively. The assessments included the Harris Hip Score (HHS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Short Form-12 (SF-12), Kujala Score, Oxford Knee Score, Oswestry Disability Index (ODI), Roland–Morris Questionnaire, American Orthopedic Foot and Ankle Society (AOFAS) Score, and Foot and Ankle Disability Index (FADI). Preoperative and 12-month postoperative radiological outcomes were then compared.

Radiological measurements

Radiological evaluations were performed preoperatively and at 12 months postoperatively. Imaging included standing anterior-posterior (AP) pelvic radiographs, AP and lateral leg length alignment radiographs, as well as standing and seated AP and lateral lumbosacral spine radiographs.

The following radiological measurements were recorded: tibiofemoral angle (TFA), hip-knee-ankle (HKA) angle, mechanical axis deviation (MAD), anatomical and mechanical lateral distal femoral angles, mechanical medial proximal tibial angle, mechanical lateral proximal femoral angle, anatomical medial proximal femoral angle, mechanical lateral distal tibial angle (mLDTA), FO, joint line convergence angle (JLCA), ankle joint orientation angle (AJOA or AJLO), heights of medial and lateral femoral condyle, PO, PT, SS (Figure 1), lumbar lordosis angle (LLA) (Figure 2), pelvic incidence (PI), tibia plafond-talus angle (PTA), leg length discrepancies (LLD), and greater trochanter height and advancement. Negative values indicate varus alignment, while positive values indicate valgus alignment.

All measurements were performed using Digital Imaging and Communications in Medicine data, utilizing the ruler and goniometer

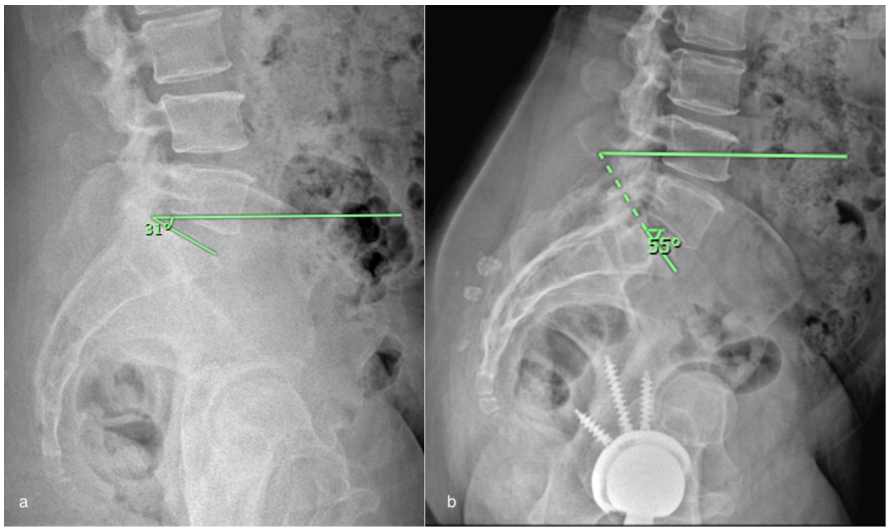

Figure 1. Preoperative and postoperative changes in sacral slope. Sacral slope was measured on standing lateral lumbosacral radiographs to assess sagittal spinal alignment before (a) and after (b) total hip arthroplasty.

tools within the M-View (Marotech, Seoul, Korea) Picture Archiving and Communication System software. All measurements were performed by a single surgeon in a blinded manner without knowledge of the patients' clinical status, and measurement reliability for LLD, HKA, TFA, and MAD was assessed by a second surgeon repeating the measurements, using the intraclass correlation coefficient (ICC). Preoperative and 12-month postoperative radiological outcomes were then compared.

Inclusion and exclusion criteria

The inclusion criteria for this study were patients diagnosed with unilateral Crowe type III or type IV hip dysplasia, with no dysplasia present in the contralateral hip.

Exclusion criteria included patients who have Crowe type I or type II dysplasia, a history of previous surgery on the affected side, failure to attend outpatient follow-up visits, or the presence of other congenital anomalies in the lower extremity unrelated to hip dysplasia.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Data distribution was assessed using the Shapiro–Wilk test. For dependent group comparisons, the paired samples *t*-test or Wilcoxon signed-rank test was used as appropriate, while independent group comparisons were performed using the Mann–Whitney *U*-test. Descriptive statistics were expressed as mean ± standard deviation or median (minimum–maximum) for continuous variables and as frequency (percentage) for categorical variables. A *P*-value <.05 was considered statistically significant.

Based on prior studies, the mean difference in MAD for the lower extremity between preoperative and postoperative measurements was taken as −8.1, with a pooled standard deviation of 8.7. Given these parameters, the required sample size for an effect size of 0.93, at a 95% CI and 0.05 significance level, with 80% power was calculated to be n=12.[17] Similarly, for spinopelvic changes, the mean

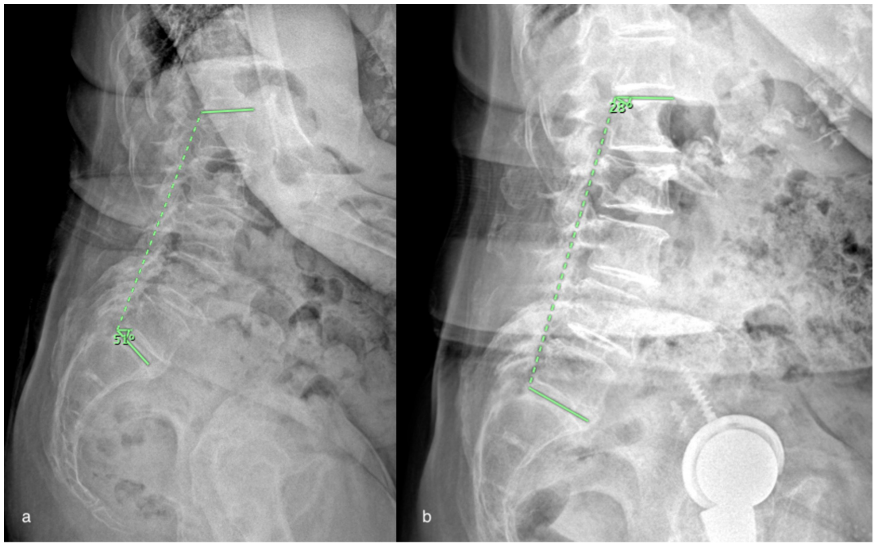

Figure 2. Pre- and postoperative changes in lumbar lordosis angle. Lumbar lordosis angle was measured on standing lateral lumbosacral radiographs to evaluate sagittal spinal adaptation before (a) and after (b) total hip arthroplasty.

difference in LLA was considered to be 12.5, with a pooled standard deviation of 17. This yielded a required sample size of n=17 for an effect size of 0.735, with 95% CI and 80% power.[26]

Results

Demographic data and surgical characteristics

A total of 33 patients were included in the study. The mean age of the participants was 52.70 ± 11.83 years (range, 33-82), with an average follow-up duration of 18.27 ± 7.04 months. Although the mean follow-up duration was 18.27 months, only the 12-month postoperative clinical and radiological outcomes were presented, as longer-term data were not available for most patients. The reported mean follow-up duration reflects the average length of patient monitoring. According to the Crowe classification, 13 patients (39.3%) had Crowe type III hips, while 20 patients (60.6%) were classified as Crowe type IV (Table 1). Femoral shortening osteotomy was performed in 18 patients (54.5%), whereas 15 patients (45.5%) did not undergo osteotomy. Among those who had osteotomy, the mean femoral shortening was 4.02 ± 1.03 cm. Complete union was achieved in all osteotomy cases (100%) (Table 2).

Table 1. Demographic data distributions

Demographic data	Descriptive statistics (n=33)
Age	52.70 ± 11.83
Gender	
Male (%)	3 (9.1)
Female (%)	30 (90.9)
Height (cm)	159.12 ± 8.09
Weight (kg)	72.58 ± 16.54
BMI (kg/m²)	28.76 ± 6.67
Follow-up duration (months)	18.27 ± 7.04
ASA Score	1.64 ± 0.65
Crowe classification	
Type 3 (%)	13 (39.3)
Type 4 (%)	20 (60.6)
Side	
Right (%)	20 (60.6)
Left (%)	13 (39.3)
Smoking	
Yes (%)	3 (9.1)
No (%)	30 (90.9)
Comorbidity	
Hypertension	
No (%)	28 (84.8)
Yes (%)	5 (15.2)
Diabetes	
No (%)	30 (90.9)
Yes (%)	3 (9.1)
Chronic obstructive pulmonary disease	
No (%)	32 (97)
Yes (%)	1 (3)
Cardiac problem	
No (%)	32 (97)
Yes (%)	1 (3)
Chronic neurological disease	
No (%)	30 (90.9)
Yes (%)	3 (9.1)
Hypothyroidism	
No (%)	30 (90.9)
Yes (%)	3 (9.1)

The data are presented as frequency (percentage) or mean ± standard deviation.
ASA, The American Society of Anesthesiologists; BMI, body mass index.

Table 2. Surgical techniques and characteristics of implants

	Descriptive statistics (n=33)
Surgical approach (%)	
Posterior	33 (100)
Femoral stem type (%)	
Zimmer & Biomet taperlock	2 (6.1)
Zimmer & Biomet wagner cone	27 (81.8)
Stryker Accolade II	3 (9.1)
Zimmer & Biomet echo bi-metric	1 (3)
Acetabular cup type (%)	
Stryker trident	24 (72.7)
Zimmer & Biomet trilogy	9 (27.3)
Acetabular cup size (%)	
40	1 (3)
42	6 (18.2)
44	6 (18.2)
46	12 (36.4)
48	4 (12.1)
50	1 (3)
52	3 (9.1)
Capsular repair (%)	
No	33 (100)
Acetabular cup fixation (%)	
Cementless	33 (100)
Femoral stem fixation (%)	
Cementless	33 (100)
Liner (%)	
Neutral	24 (72.7)
Offset	9 (27.3)
Femoral head size (%)	
28	2 (6.1)
32	13 (39.4)
36	17 (51.5)
40	1 (3)
Femoral head offset (%)	
−5	1 (3)
−3.5	23 (69.7)
0	6 (18.2)
7	1 (3)
10.5	2 (6.1)
Type of femoral head (%)	
Ceramic	31 (93.9)
Metal	2 (6.1)
Acetabular autograft usage (%)	
No	31 (93.9)
Yes	2 (6.1)
Postoperative drain usage (%)	
No	24 (72.7)
Yes	9 (27.3)
Plate usage (%)	
No	27 (81.8)
Yes	6 (18.2)
Number of screws (%)	
1	5 (15.2)
2	19 (57.6)
3	9 (27.3)
Femoral shortening (%)	
No	15 (45.4)
Yes	18 (54.5)
Shortening length (cm)	4.02 ± 1.03
Bone union (%)	
Yes	18 (100)
Complications (%)	
No	27 (81.8)
Yes	6 (18.2)
Duration of surgery (minutes)	188.33 ± 38.66

The data are presented as frequency (percentage) or mean ± standard deviation.

Postoperative complications were observed in 6 patients (18.2%), while 27 patients (81.8%) experienced no complications. One patient developed transient sciatic nerve palsy, and early postoperative hip dislocations occurred in 5 patients within 2 months after surgery. All dislocations were successfully managed with closed reduction, and no recurrent dislocations were noted during follow-up. The patient with sciatic nerve palsy was asymptomatic at 1 year postoperatively. The mean operative time was 188.33 ± 38.66 minutes (Table 2).

Clinical outcomes

Significant postoperative improvements were observed in both ipsilateral hips (HHS: $P < .001$; WOMAC: $P < .001$) and contralateral hips (HHS: $P = .001$; WOMAC: $P = .003$). In terms of knee function, a significant increase was detected only in the ipsilateral WOMAC score ($P = .038$). Although the other knee parameters demonstrated a mild trend toward improvement postoperatively, these changes did not reach statistical significance (all $P > .05$) (Table 3).

Significant improvement was observed in lumbar spine–related disability scores (ODI $P = .014$; Roland–Morris $P = .004$). Although AOFAS and FADI scores showed a mild postoperative increase, these changes did not reach statistical significance (all $P > .05$). In contrast, both the physical and mental components of the SF-12 demonstrated significant improvement (both $P < .001$) (Table 3).

Radiological measurements

Preoperatively, the ipsilateral lower limb demonstrated marked valgus alignment; although a significant postoperative improvement was observed, full neutral alignment was not achieved. On the operated side, MAD ($P < .001$), JLCA ($P = .024$), and AJLO ($P = .049$) demonstrated significant postoperative improvements with corresponding large-to-small effect sizes (MAD: $d = -0.93$; JLCA: $d = -0.48$; AJLO: $d = 0.34$) (Table 4). On the contralateral side, a preoperative varus alignment was present, and postoperative changes were minimal; although there was a slight trend toward improvement, the differences did not reach statistical significance (all $P > .05$). Meanwhile, leg length discrepancy improved significantly, with an average correction of approximately 2.6 cm ($P < .001$) ($d = 0.92$) (Table 4).

Sacral slope remained within physiological limits pre- and postoperatively but demonstrated a significant postoperative increase ($P = .027$) ($d = 0.35$). Lumbar lordosis angle decreased significantly after surgery ($P < .001$) ($d = -1.30$). Although other spinopelvic parameters showed mild postoperative improvement, these changes were not statistically significant (all $P > .05$) (Table 4).

Table 3. Comparison of preoperative and postoperative clinical outcomes of patients

	Preoperative	Postoperative	P*
Hip scores			
HHS ipsilateral	34 (19-56)	83 (42-91)	**<.001**
WOMAC ipsilateral	68 (23-92)	15 (0-53)	**<.001**
HHS contralateral	87 (25-100)	92 (31-100)	**.001**
WOMAC contralateral	17 (0-70)	0 (0-72)	**.003**
SF-12			
Physical	30 (25-44)	47 (21-54)	**<.001**
Mental	36 (25-49)	49 (21-56)	**<.001**
Knee scores			
Kujala ipsilateral	86 (38-100)	97 (30-100)	.147
WOMAC ipsilateral	22 (0-48)	0 (0-68)	**.038**
Oxford ipsilateral	41 (18-48)	48 (12-48)	.214
Kujala contralateral	86 (0-100)	81 (0-100)	.551
WOMAC contralateral	17 (0-48)	2 (0-69)	.506
Oxford contralateral	38 (0-48)	40 (0-48)	.925
Lumbar scores			
Oswestry	28 (0-80)	16 (0-55)	**.014**
Roland–Morris	15 (0-24)	5 (0-24)	**.004**
Foot/ankle scores			
AOFAS ipsilateral	100 (30-100)	100 (30-100)	.854
FADI ipsilateral	100 (50-100)	100 (50-100)	.564
AOFAS contralateral	100 (0-100)	100 (0-100)	.345
FADI contralateral	100 (0-100)	100 (0-100)	.528

Bold values indicate statistical significance ($P < .05$).
AOFAS, American Orthopedic Foot and Ankle Society; FADI, Foot and Ankle Disability Index; HHS, Harris Hip Score; SF-12, Short Form-12; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.
*Wilcoxon test. Data are presented as median (min–max).

Table 4. Comparison of preoperative and postoperative values of radiological measurements

	Preoperative	Postoperative	P*
Leg length ipsilateral (mm)	915.15 ± 72.78	941.90 ± 82.56	**<.001**
Leg length contralateral (mm)	959 ± 69.70	959.30 ± 72.79	.904
Leg length discrepancy (mm)	−43.84 ± 32.57	−17.39 ± 24.54	**<.001**
MAD (mm) ipsilateral	17.17 ± 9.99	5.51 ± 14.55	**<.001**
MAD (mm) contralateral	−13.59 ± 15.16	−12.37 ± 15.28	.507
TFA ipsilateral	7.91 ± 6.91	8.52 ± 7.34	.673
TFA contralateral	0.15 ± 7.45	1.48 ± 5.23	.166
HKA ipsilateral	4.76 ± 6.44	3.15 ± 4.95	.112
HKA contralateral	−3.94 ± 5.20	−4.18 ± 5.54	.734
aLDFA ipsilateral	79.30 ± 5.44	78.79 ± 4.98	.429
aLDFA contralateral	83.94 ± 4.34	84.06 ± 4.44	.823
mLDFA ipsilateral	84.18 ± 4.29	84.39 ± 4.11	.780
mLDFA contralateral	89.91 ± 3.82	89.64 ± 3.74	.660
mMPTA ipsilateral	88 ± 2.90	88.61 ± 2.71	.331
mMPTA contralateral	88.30 ± 2.95	88.21 ± 2.98	.869
HMFC ipsilateral	14.22 ± 2.80	15.26 ± 2.93	.083
HMFC contralateral	13.42 ± 2.88	12.42 ± 2.85	.068
HLFC ipsilateral	5.85 ± 2.28	6.16 ± 2.95	.478
HLFC contralateral	7.67 ± 2.71	7.28 ± 2.86	.514
FO ipsilateral	37.61 ± 5.23	37.09 ± 7.32	.715
FO contralateral	42.56 ± 8.38	42.31 ± 8.64	.768
mLPFA ipsilateral	89.30 ± 15.71	85.79 ± 10.96	.308
mLPFA contralateral	97.21 ± 12.74	96.67 ± 12.94	.687
aMPFA ipsilateral	80.55 ± 14.71	87.64 ± 12.62	.059
aMPFA contralateral	76.91 ± 13.61	77.09 ± 12.92	.927
mLDTA ipsilateral	85.79 ± 4.83	86.24 ± 6.38	.695
mLDTA contralateral	90.27 ± 3.61	90.82 ± 4.14	.291
JLCA ipsilateral	−0.73 ± 3.68	−2.33 ± 2.90	**.024**
JLCA contralateral	−3.30 ± 3.68	−3.67 ± 3.81	.483
AJLO ipsilateral	4.94 ± 3.93	6.39 ± 4.60	**.049**
AJLO contralateral	−4.79 ± 5.13	−5.45 ± 5	.463
PTA ipsilateral	−0.30 ± 1.57	−0.30 ± 1.94	1.000
PTA contralateral	0.09 ± 1.91	0.73 ± 1.71	.085
PO	4.24 ± 8.32	3.09 ± 6.84	.338
SS standing	45.48 ± 12.59	49.85 ± 12.30	**.027**
SS sitting	17.12 ± 10.73	22.27 ± 12.15	**.022**
SS change	28.36 ± 14.25	27.58 ± 13.86	.787
Pelvic incidence	57.24 ± 15.16	62.12 ± 13.70	.078
Pelvic tilt	12.55 ± 12.52	14.09 ± 10.72	.566
Lumbar lordosis angle	61.30 ± 11.60	43.48 ± 15.59	**<.001**

Bold values indicate statistical significance ($P < .05$).
aLDFA and mLDFA, anatomical and mechanical lateral distal femoral angle; AJLO, ankle joint orientation angle; aMPFA, anatomical medial proximal femoral angle; FO, femoral offset; HKA, hip-knee-ankle angle; HMFC and HLFC, medial and lateral femoral condyle heights; JLCA, joint line convergence angle; MAD, mechanical axis deviation; mLDTA, mechanical lateral distal tibial angle; mLPFA, mechanical lateral proximal femoral angle; mMPTA, mechanical medial proximal tibial angle; PO, pelvic obliquity; PTA, tibia plafond-talus angle; SS, sacral slope; TFA, tibiofemoral angle.
*Paired samples *t*-test. Data are presented as mean ± standard deviation.

Table 5. Measurements in 2 groups: with and without osteotomy

	Without osteotomy	With osteotomy
Leg length discrepancy (cm)		
Preoperative	−3.03 ± 3.34	−5.5 ± 2.7
Postoperative	−0.5 ± 1.32	−2.8 ± 2.7
P	**.007**	**<.001**
MAD ipsilateral (cm)		
Preoperative	1.36 ± 1	2 ± 0.91
Postoperative	0.13 ± 1.4	0.8 ± 1.43
P	**<.001**	**.005**
P-value of the intergroup change	.784	
MAD contralateral (cm)		
Preoperative	−1.46 ± 1.45	−1.27 ± 1.6
Postoperative	−1.19 ± 1.49	−1.27 ± 1.63
P	.320	.988
P-value of the intergroup change	.417	
Trochanteric advancement (cm)	2.54 ± 1.03	6.93 ± 2.61
Shortening length (cm)	0	4.02 ± 1.03
Limb lengthening (cm)	2.54 ± 1.03	2.9 ± 2.24

Bold values indicate statistical significance ($P < .05$).
MAD, mechanical axis deviation.

Leg length and mechanical axis deviation analysis

In the osteotomy group (n=18), the mean length of the resected femoral segment was 4.02 ± 1.03 cm. Preoperative LLD was −5.5 ± 2.7 cm, improved to −2.8 ± 2.7 cm postoperatively. Greater trochanter advancement averaged 6.93 ± 2.61 cm, resulting in a net leg lengthening of 2.9 ± 2.24 cm after subtracting the resected segment length. On the dysplastic side, MAD significantly decreased from 2.0 ± 0.91 cm to 0.8 ± 1.43 cm postoperatively (P=.004), while no significant change was observed on the contralateral side (preoperative: 1.27 ± 1.6 cm; postoperative: 1.27 ± 1.63 cm; P=.988) (Table 5).

In the non-osteotomy group (n=15), LLD improved from −3.03 ± 3.34 cm preoperatively to −0.5 ± 1.32 cm postoperatively. Since no osteotomy was performed, greater trochanter advancement corresponded to actual leg lengthening and was measured as 2.54 ± 1.03 cm. Mechanical axis deviation on the dysplastic side significantly decreased from 1.36 ± 1.0 cm to 0.13 ± 1.4 cm ($P < .001$). Although MAD on the contralateral side decreased from −1.46 ± 1.45 cm to −1.19 ± 1.49 cm, this change was not statistically significant (Table 5).

No significant differences in MAD changes between osteotomy and non-osteotomy groups were observed on either the operated side or the contralateral side (all $P > .05$) (Table 5).

Measurement reliability

Measurement reliability was assessed for LLD, HKA, TFA, and MAD using the ICC. The analysis demonstrated statistically significant and high agreement among repeated measurements (all $P < .001$) (Table 6).

Discussion

In this prospective study of 33 patients with unilateral Crowe type III-IV DDH, significant postoperative improvements were observed in hip function, including HHS (ipsilateral: $P < .001$; contralateral: P=.001), WOMAC (ipsilateral: $P < .001$; contralateral: P=.003), SF-12 (physical and mental: both $P < .001$), ODI (P=.014), Roland–Morris (P=.004), and ipsilateral knee WOMAC scores (P=.038). Radiographically, significant reductions were observed in LLD ($P < .001$) and ipsilateral MAD ($P < .001$), along with increases in JLCA (P=.024) and AJLO (P=.049). Spinopelvic parameters demonstrated an increase in SS (P=.027) and a decrease in LLA ($P < .001$). These findings suggest that restoration of the anatomical hip center through THA improves spinopelvic and lower-extremity alignment, although its effects on distal joints appear more limited.

In patients with Crowe type III-IV DDH, THA can substantially alter lower-extremity alignment. Preoperative valgus knee alignment is often attributed to femoral deformities. The findings are consistent with Zhao et al,[4] who reported that increased medial femoral condyle height may reduce LDFA and contribute to valgus alignment.[17,26] In the cohort, the operated limb demonstrated preoperative valgus MAD that improved significantly after surgery, approaching near-normal alignment, whereas contralateral MAD remained unchanged. The HKA angle also showed a preoperative valgus tendency that decreased postoperatively but did not reach statistical significance. These findings partly align with previous studies suggesting that acetabular reconstruction in the true acetabulum can influence lower-limb alignment, although reported correction patterns vary among studies.[4,16,17,27]

Table 6. Intraclass correlation analysis results

	Intraobserver			Interobserver		
	Intraclass Correlation	CI (95%)	*P*	Intraclass Correlation	CI (95%)	*P*
Leg length ipsilateral preoperative	0.926	0.850-0.964	**<.001**	0.823	0.641-0.912	**<.001**
Leg length ipsilateral postoperative	0.865	0.844-0.962	**<.001**	0.822	0.640-0.912	**<.001**
Leg length contralateral preoperative	0.923	0.726-0.933	**<.001**	0.813	0.622-0.908	**<.001**
Leg length contralateral postoperative	0.906	0.810-0.954	**<.001**	0.805	0.606-0.904	**<.001**
MAD ipsilateral preoperative	0.994	0.987-0.997	**<.001**	0.898	0.794-0.950	**<.001**
MAD ipsilateral postoperative	0.992	0.984-0.996	**<.001**	0.975	0.949-0.988	**<.001**
MAD contralateral preoperative	0.984	0.968-0.992	**<.001**	0.963	0.924-0.982	**<.001**
MAD contralateral postoperative	0.996	0.993-0.998	**<.001**	0.938	0.874-0.969	**<.001**
HKA ipsilateral preoperative	0.996	0.992-0.998	**<.001**	0.986	0.972-0.993	**<.001**
HKA ipsilateral postoperative	0.996	0.992-0.998	**<.001**	0.976	0.951-0.988	**<.001**
HKA contralateral preoperative	0.994	0.988-0.997	**<.001**	0.869	0.735-0.935	**<.001**
HKA contralateral postoperative	0.997	0.993-0.998	**<.001**	0.992	0.983-0.996	**<.001**
TFA ipsilateral preoperative	0.997	0.993-0.998	**<.001**	0.969	0.937-0.985	**<.001**
TFA ipsilateral postoperative	0.998	0.996-0.999	**<.001**	0.942	0.883-0.971	**<.001**
TFA contralateral preoperative	0.998	0.997-0.999	**<.001**	0.974	0.948-0.987	**<.001**
TFA contralateral postoperative	0.991	0.981-0.995	**<.001**	0.969	0.936-0.984	**<.001**

The bold values in indicate statistically significant results ($P < .05$).
HKA, hip-knee-ankle; MAD, mechanical axis deviation; TFA, tibiofemoral angle.

The JLCA is an important parameter in evaluating lower-extremity alignment. In the series, the operated limb showed preoperative JLCA values within normal limits but demonstrated a significant postoperative shift toward varus (P=.024). On the contralateral side, JLCA was already in varus preoperatively and remained unchanged after surgery (P=.483). These findings differ from those reported by Kocabıyık et al,[17] who observed stable JLCA values bilaterally before and after THA. The postoperative varus shift in the cohort may reflect chronic loading patterns or intra-articular adaptations. Although LDFA and MPTA did not change significantly, improvement in MAD may have contributed to the observed JLCA shift. Overall, these findings underscore the importance of restoring mechanical alignment in patients with DDH to optimize lower-limb biomechanics following THA.

In the literature, ankle alignment has rarely been addressed. Kocabıyık et al[17] reported that both AJLO and PTA improved toward neutral on the operated side following THA. In contrast, the study demonstrated that PTA and mLDTA remained within physiological limits both pre- and postoperatively; however, the AJLO of the operated limb exhibited a significant postoperative shift toward valgus angulation (P=.049), while the contralateral side remained stable (P=.463). Unlike prior findings, AJLO did not return to neutral in the series.

This discrepancy can be attributed to several potential factors. First, underlying rotational deformities of the tibia or talus, which are not fully corrected by THA, may contribute to persistent abnormal ankle alignment. Second, radiographic measurement techniques may have inherent limitations in accurately detecting subtle rotational or compensatory changes. Notably, the persistence of valgus alignment at the ankle following THA may reflect broader compensatory adaptations within the distal kinetic chain in response to long-standing hip dysplasia. These observations suggest that although THA effectively restores proximal alignment parameters, its corrective influence on distal joints may remain incomplete. Recognition of these residual alterations underscores the necessity for comprehensive, multi-joint evaluations in future studies, as persistent ankle malalignment could adversely affect load distribution, gait mechanics, and long-term functional outcomes.

Total hip arthroplasty in patients who have DDH not only restores the hip joint but also exerts a substantial influence on spinopelvic alignment. In DDH, the abnormal position of the femoral head alters PT and sagittal balance, triggering compensatory mechanisms throughout the spinopelvic axis. In the present study, a significant postoperative increase in SS and a decrease in LLA were observed, suggesting a reorganization of the sagittal alignment following THA. Consistent with previous literature, spinopelvic mobility has been shown to change and, in some cases, normalize following THA, rather than remaining static.[28] However, despite growing evidence, spinopelvic parameters are not yet routinely incorporated into clinical practice, and a substantial proportion of orthopedic surgeons do not consistently consider these factors during preoperative planning.[29]

The findings are directionally consistent with those reported by Çağlar et al,[25] although the study demonstrated statistically significant changes that were not evident in some previous series. Nevertheless, the literature remains heterogeneous; whereas several studies have described meaningful postoperative improvements in pelvic parameters,[22,23] others have reported minimal or no changes.[24] As suggested by Ben-Galim et al,[30] these discrepancies may be attributed to differences between standardized radiographic positioning and natural standing or gait posture, as well as reduced spinal flexibility due to long-standing deformity. Accordingly, despite clinically meaningful improvement in low back pain, the absence of complete normalization in sagittal alignment in the cohort may reflect limited reversibility of chronic compensatory adaptations. Although SS and lumbar lordosis remained within physiological ranges, significant postoperative directional changes were observed. Importantly, although the postoperative changes in SS and lumbar lordosis reached statistical significance, both parameters remained within physiological limits in the preoperative and postoperative periods. Therefore, these findings should be interpreted cautiously. Rather than representing a definitive correction of sagittal alignment, the observed changes may reflect early adaptive biomechanical responses following restoration of the hip center after THA. This distinction between statistical significance and clinical relevance should be considered when interpreting spinopelvic adaptations in patients with high-grade DDH.

Consistent with this concept, Morimoto et al[26] demonstrated significant improvement in SS and LLA after true-acetabular reconstruction in Crowe IV hips, with postoperative LLA strongly correlating with PI. In contrast, Çağlar and Can observed no significant radiographic changes in unilateral high-dislocation cases, although they suggested that larger cohorts might reveal subtle differences.[24,25] Similarly, Ren et al[21] reported markedly elevated preoperative SS and LLA values in Crowe IV DDH, reflecting severe sagittal malalignment, while Zhang et al[31] associated altered spinopelvic parameters with sagittal–coronal imbalance and poorer functional outcomes. Overall, these findings suggest that spinopelvic adaptations in DDH depend on disease severity, chronicity, and the accuracy of anatomical reconstruction. The results indicate that although THA provides substantial clinical improvement, complete normalization of spinopelvic alignment may not occur in the early postoperative period. Future studies should incorporate dynamic assessments such as gait analysis and lumbopelvic mobility evaluation in addition to static radiographic measurements.

Studies show significant improvements in HHS, WOMAC, SF-12, and ODI after THA in DDH patients. These benefits extend beyond the hip to the entire musculoskeletal system, including the knee, ankle, foot, and spine, especially in complex Crowe type III and IV cases.[24,32-34] However, clinical outcomes for the knee and foot–ankle are rarely studied. The study uniquely evaluates these areas alongside hip outcomes, finding significant postoperative improvements in hip scores and lumbar spine measures, as well as a novel significant improvement in the ipsilateral knee WOMAC score.

Several limitations should be acknowledged. First, this study includes only short-term (12-month) follow-up, which may be insufficient to evaluate potential arthrotic progression in the knee and ankle joints. Second, although the surgical protocol was standardized, the use of different implant types may have influenced postoperative alignment. Third, analyzing Crowe type III and IV hips together may have masked subtype-specific alignment patterns. However, subgroup analysis was not performed because the sample size of each subgroup was relatively small, which could reduce statistical power and potentially lead to misleading interpretations. Fourth, due to the limited sample size and uneven age distribution between the Crowe III and IV groups, an age-stratified analysis investigating the relationship between lower-extremity alignment and spinopelvic changes couldn't be performed. Fifth, correction of PO after THA may influence contralateral hip biomechanics and lumbar symptoms; however, these

secondary compensatory effects were not specifically evaluated in the present study. Finally, the absence of full-spine radiographs prevented coronal alignment assessment and may have underestimated postoperative biomechanical adaptation.

Despite these limitations, this study is among the first to radiographically evaluate ankle alignment while simultaneously comparing knee and foot–ankle clinical outcomes in patients who have unilateral DDH. The findings demonstrate that although valgus alignment of the operated limb improves after THA, full neutral correction is not consistently achieved, whereas the contralateral limb largely maintains its preexisting varus configuration. Additionally, although SS and lumbar lordosis remain within physiological ranges, both parameters exhibit significant postoperative directional changes, underscoring the broader influence of hip reconstruction on spinopelvic dynamics.

Given these complex anatomical and functional adaptations, further prospective, multicenter studies with long-term follow-up are necessary to validate and generalize these results. Future investigations should incorporate subgroup analyses, 3-dimensional spinopelvic motion assessment, and gait analysis to better elucidate the interaction between dynamic lumbopelvic mechanics and lower-extremity load-transfer patterns. The integration of such advanced biomechanical evaluation techniques will enhance understanding of postoperative compensatory mechanisms, inform rehabilitation strategies, and potentially improve overall clinical outcomes.

While the majority of studies in the literature have focused on the hip and knee joints, the effects of THA on the pelvis, spine, and ipsilateral knee in high hip dislocation have already been widely investigated. However, the potential impact of THA on more distal joints has received considerably less attention. Therefore, the present study provides a comprehensive lower extremity assessment, including ankle alignment and foot–ankle clinical outcomes, in patients with Crowe type III and IV DDH. This broader perspective allows for a more holistic understanding of biomechanical changes following THA and underscores the interdependence of adjacent joints in the kinetic chain. Including these underexplored regions enhances the clinical relevance of the findings and highlights the need for multijoint evaluation in future studies.

As a conclusion, in unilateral high-grade DDH, THA not only restores hip function but also contributes to systematic realignment of the lower extremity and spinopelvic region. Although alignment improvement is more pronounced on the operated side, THA corrects proximal biomechanics and partially alleviates distal malalignment, thereby supporting global postural restoration and enhancing functional recovery.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

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