Wang *et al. Journal of Orthopaedic Surgery and Research* (2025) 20:489
https://doi.org/10.1186/s13018-025-05877-y

Journal of Orthopaedic Surgery and Research

SYSTEMATIC REVIEW

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Knee morphology and patella malalignment in neglected developmental dysplasia of the hip: a systematic review and meta-analysis

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Abstract

Purpose To quantitatively analyze the structural changes of the knee in patients with neglected developmental dysplasia of the hip (DDH).

Methods PubMed, Embase, Web of Science, and Cochrane Library databases were searched to identify studies comparing the morphological parameters of the knee between DDH patients and healthy individuals. Data on rotational and mechanical parameters of the lower limb, rate of occasional anterior knee pain (AKP), and knee morphological parameters, were extracted. Review Manager and R statistic software were used to perform the statistical analysis.

Results Nine studies with a total of 790 legs in 521 neglected DDH patients and 431 legs in 303 health subjects were included. Patients were predominantly female (88.3%). The Crowe classification is most commonly used to assess the severity of DDH. The total incidence of occasional AKP ranged from 8.6 to 20.6%, with an overall pooled rate of 14.4% (95%CI = 9.8–19.8%). In patients with neglected DDH, significant increases ($P < 0.0001$) were observed in femoral anteversion (weighted mean: 39.1° vs. 17.7°), knee torsion (weighted mean: 9.0° vs. 1.6°), and the vertical dimension of the medial femoral condyle (weighted mean: 13.8 mm vs. 11.6 mm), along with a significant decrease in the lateral distal femoral angle (weighted mean: 82.1° vs. 84.8°), which can lead to torsion deformity of the lower limb and valgus inclination of the distal femoral articular surface. Compared with the intact subjects, DDH knees demonstrated an increased sulcus angle (weighted mean: 144.9° vs. 137.5°; $P < 0.0001$), decreased trochlear depth (weighted mean: 3.1 mm vs. 4.5 mm; $P < 0.0001$), increased lateral shift of the patella (5.1 mm vs. 3.8 mm, $P = 0.06$), and increased patellar tilt angle (weighted mean: 18.2° vs. 13.2°; $P < 0.0001$). These findings were associated with developmental dysplasia of femoral trochlear and patellar instability.

Conclusion Developmental dysplasia of the hip leads to patellar malalignment and developmental changes in the bony anatomy of the knee joint, including the development of a valgus deformity of the lower extremity and trochlear dysplasia. These findings may be associated with patellar instability.

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Level of evidence III, systematic review.

Registration This study was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42025640292).

Keywords Developmental dysplasia of the hip (DDH), Knee morphology, Trochlear dysplasia, Valgus deformity, Patellar instability

Introduction

The impact of developmental dysplasia of the hip (DDH) ranges from acetabular dysplasia to complete dislocation of the hip. Situated at the junction of the axial and appendicular skeletons, the hip joint undergoes structural changes due to DDH, potentially affecting parameters of the axial skeleton [1]. Previous studies investigating the natural history of DDH from infancy to adulthood have demonstrated its association with valgus deformity of the knee and femoral trochlear dysplasia [1, 2]. Quantitative research by Kandemir et al. [3] revealed that DDH increases the vertical dimension of the medial femoral condyle and mechanical axis deviation, which may explain valgus malalignment. Other studies suggest that hip adduction contracture could lead to dysplasia of the distal femoral epiphyseal plate, resulting in mechanical malalignment in the coronal plane of the knee joint [3, 4]. Recent finding indicates a strong association between dysplasia of the distal femoral epiphyseal plate and trochlear dysplasia [5]. Additionally, quantitative studies have identified knee torsion deformity [6, 7] and patellar alignment abnormalities [8] in patients with hip dysplasia. These morphological changes in the knee are critically important for surgical decision-making in knee interventions.

Previous studies [3, 9, 10] suggested that some patients with neglected DDH are prone to symptomatic patellofemoral joint (PFJ) disease, including occasional anterior knee pain (AKP), damage to cartilage and soft tissue stabilizing structures, patellar instability, or osteoarthritis. Moreover, most of these patients exhibit altered morphological parameters of the distal femur, patellofemoral joint, and patella, which may explain these symptoms. Importantly, for such patients undergoing knee surgery, additional evaluation of osseous morphological parameters is essential, particularly in cases involving knee soft tissue reconstruction or joint replacement. To the best of our knowledge, no systematic review or meta-analysis has been conducted to assess the morphological changes in the knee joint among patients with neglected DDH.

This systematic review and meta-analysis aims to quantitatively analyze the structural changes of the knee joint and investigate the pooled rate of occasional AKP in patients with neglected DDH.

Methods

This study was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42025640292). This work was conducted in line with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and AMSTAR (Assessing the Methodological Quality of Systematic Reviews) Guidelines [11].

Search strategy and eligibility criteria

The search strategy was used to identify all publications eligible for inclusion in the review. PubMed, Embase, Web of Science, and Cochrane Library databases were searched in December 2024 (updated in January 2025). The search terms are listed in Supplementary Table 1. Specific search strategies were developed for each database and references of the identified studies were checked for potential eligibility.

The following inclusion criteria were used to identify eligible studies: comparing the morphological parameters of the knee between DDH patients and healthy individuals. Furthermore, this study excluded non-English language reports, case reports, conference abstracts/posters, or reviews. After the removal of duplicates, two orthopedic surgeons independently reviewed the titles and abstracts to screen for potentially eligible studies. Full texts were then assessed independently by the same two reviewers to identify the final list of publications suitable for inclusion in the current study. If disagreement occurred, a third senior orthopedic surgeon was consulted for final assessment and consensus.

Data extraction

Each included article was abstracted regarding study features, patient characteristics, physical examination information, and outcome measures. Study characteristics included author name, publication date, study design, level of evidence, and number of patients/hips/knees. Patient data included sex, age, and DDH classifications. Physical examination information primarily includes the incidence of occasional anterior knee pain (AKP), patellar instability, and dislocation. Outcome measures consisted of (1) rotational and mechanical parameters of the lower limb, such as femoral anteversion angle (FAA), knee torsion, tibial torsion, anatomic lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA), and mechanical axis deviation; (2) knee morphological parameters, such as dimensions of the medial and lateral femoral condyles (MFC and LFC), sulcus angle (SA), femoral trochlear depth (FTD), patellar tilt angle (PTA), lateral shift of the patella (LSP), etc. The data extraction of the included studies was conducted independently by two reviewers.

Quality assessment

The quality of the included studies was assessed independently by two reviewers. In this regard, the Methodological Index for Non-Randomized Study (MINORS) [12] for cohort studies was used. Items on the questionnaire were scored as follows: 0 if not reported, 1 if reported but inadequate, and 2 if reported and adequate. The maximum score for non-comparative studies was 16, with a score of 13 to 16 being considered the low risk of bias. The maximum score for comparative studies was 24, with scores of 21 to 23 considered to be at low risk of bias. Otherwise, studies were considered to have a high risk of bias. When disagreement occurred, a third senior orthopedic surgeon was consulted for final consensus. The intraclass correlation coefficient was calculated in SPSS software (version 26.0, IBM, Armonk, NY, USA) and used to evaluate the reliability of the publication bias assessment [13].

Statistical analysis

Review Manager (version 5.3 from Cochrane Collaboration) and R statistic software were used to perform the statistical analysis, with $P<0.05$ as a threshold of statistical significance. In this study, the mean-variance estimation method described by Lou et al. [14] and Wan et al. [15] was used to estimate means (standard deviations) from median and interquartile ranges in some studies. For continuous data with standard deviation, meta-analysis was performed to calculate the weighted mean difference (WMD) with 95% confidence intervals (CIs) using the inverse variance (IV) method. When comparing the incidence of dichotomous data, such as residual J-sign, the Odds Ratio (OR) was calculated using the Mantel-Haenszel (M-H) method. The I^2 statistic and Q test were used to measure heterogeneity. If $I^2<50\%$ and the p-value for the Q test > 0.05, the studies were interpreted as minimally heterogeneous, and a fixed-effects model was applied for the meta-analysis. A random-effects model was applied when $I^2>50\%$ or the p-value for the Q test < 0.05, which indicated that the data were of high heterogeneity. R statistic software was used to calculate the rate of occasional anterior knee pain. Other results were presented as a descriptive summary.

Results

Literature search and quality assessment

A total of 2064 studies were identified in the initial search and 9 articles were finally included for analysis (Fig. 1). All studies were comparative articles. The median MINORS scores of the two reviewers were 21 (range: 21 to 22) and 22 (range: 21 to 23) for all studies, respectively. The study features are summarized in Table 1.

Patient characteristics

A total of 790 legs in 521 neglected DDH patients and 431 legs in 303 health subjects were included. In patients with developmental dysplasia of the hip, the reported cases of unilateral DDH are comparable to those of bilateral DDH (162 vs. 166). Females were more likely to develop DDH than males (88.3% [394/446] vs. 21.7% [52/446]). The mean age of patients ranged from 21.6 to 56 years. The Crowe classification is most commonly used to assess the severity of DDH [3, 6, 7, 10, 16], followed by the Hartofilakidis classification [17–19]. Only one study utilized the combined lateral center-edge angle (LCE) and femoral anteversion angle (FAA) for evaluating DDH [8]. The characteristics of the patients are summarized in Table 1.

Occasional anterior knee pain

Four studies reported the rate of occasional AKP in patients with neglected DDH [3, 16, 18, 19]. The total incidence of AKP ranged from 8.6 to 20.6%, with an overall pooled rate of 14.4% (common effect model, 95%CI = 9.8–19.8%) (Fig. 2). One study was excluded from this analysis because it included AKP as an inclusion criterion (with an AKP incidence of 100%) [10].

Rotational deformity and knee malalignment

Five studies compared the differences in FAA between DDH and control groups [3, 6, 8, 17]. The pooled analysis showed that the FAA increased significantly in patients with neglected DDH (weighted mean: 39.1° vs. 17.7°; WMD = 21.4°; $P<0.0001$). Two similiar studies assessed knee torsion in patients with hip dysplasia and found that this deformity was greatly higher in the DDH group (DDH vs. control knees, 9.0° vs. 1.6°, $P<0.001$) [6, 7]. In addition, the current study has not found any differences in tibial torsion between the two sample groups [3]. Regarding knee alignment, the pooled results indicated that patients with DDH exhibit a significant valgus knee deformity,

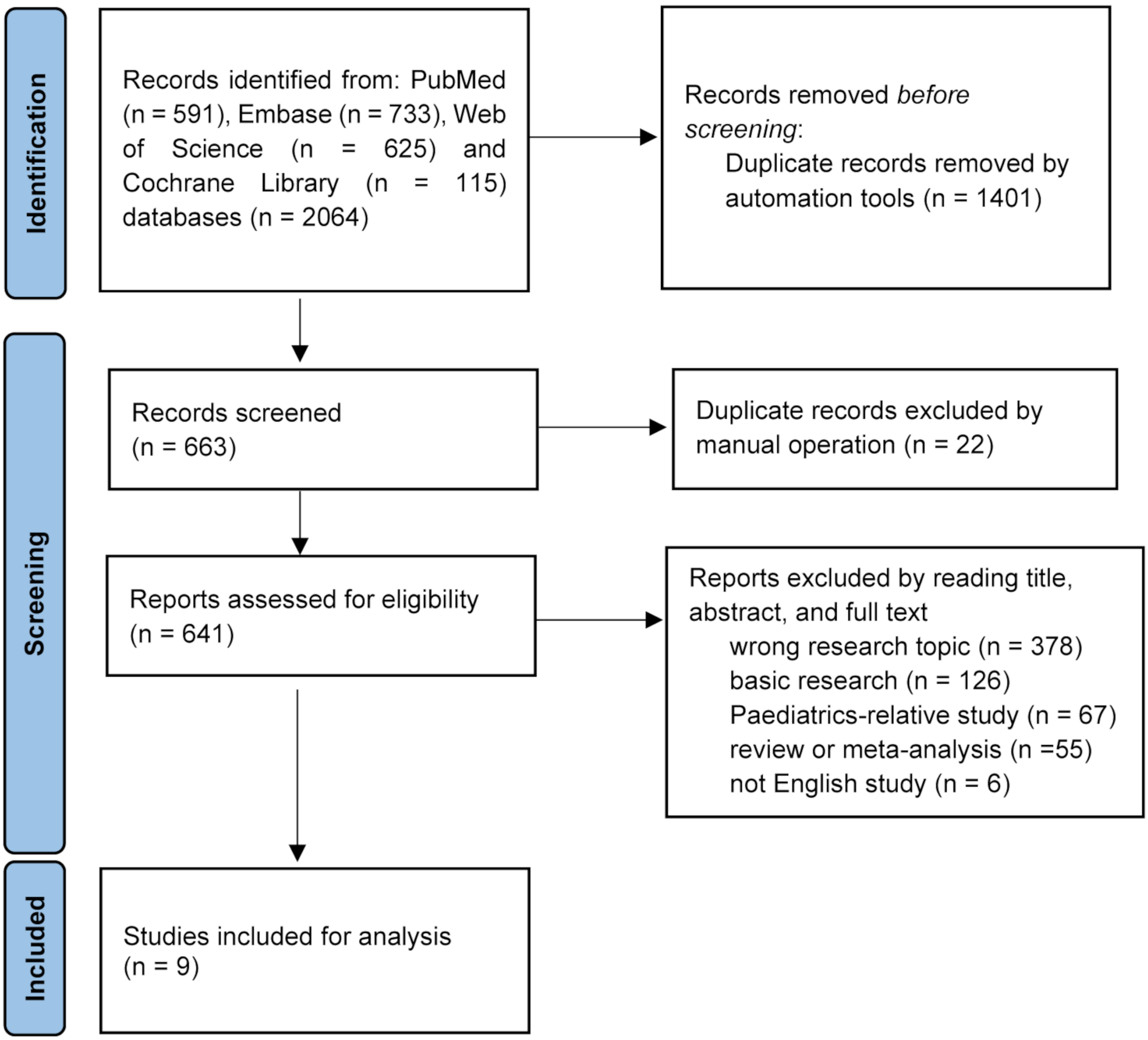

Fig. 1 Flow diagram of the selection of studies

characterized by a decrease in the LDFA (weighted mean: 82.1° vs. 84.8°; WMD = -2.8°; $P < 0.0001$) and an increase in the mechanical axis deviation (Table 2 and Fig. 3).

Morphology of femoral condyles

Four studies evaluated the morphology of the distal femoral condyles in patients with DDH. The pooled analysis showed that the patients with DDH had significantly decreased horizontal dimension of the lateral femoral condyle (HDLFC) (weighted mean: 38.4 mm vs. 41.8 mm; WMD = -3.4 mm; $P < 0.0001$) and increased vertical dimension of the medial femoral condyle (VDMFC) (weighted mean: 13.8 mm vs. 11.6 mm; WMD = 2.2 mm; $P < 0.0001$) (Fig. 4). This finding was associated with the increased valgus inclination of the distal femoral articular surface.

Furthermore, pooled results also showed that DDH knees had a smaller anteroposterior diameter of MFC (weighted mean: 52.5 mm vs. 57.1 mm; WMD = -4.6 mm; $P < 0.0001$), while the differences in anteroposterior diameter of LFC and condyle asymmetry were not significant ($P > 0.05$) (Fig. 5).

Trochlear dysplasia and patella malalignment

Five studies reported the morphology of femoral trochlear and patellar alignment in patients with DDH. The pooled analysis showed that the patients with DDH demonstrated an increased sulcus angle (weighted mean: 144.9° vs. 137.5°; WMD = 7.4°;

Table 1 Study characteristics

Study	Groups	Subjects	Legs	Male/Female	Age, years	Bilateral DDH	DDH system	DDH-type	Occasional AKP, %	MINORS (R1/R2)
Kandemir 2002 [3]	DDH	34	44	2/32	44.2 (17–68)	10	Crowe system	16 type III-IV, 12 type I-II, 6 hypoplasia	7/34, 21%	21/21
	Control	10	20	1/9	38.9 (18–58)	NA	NA	NA	NA	NA
Akşahin 2012 [10]	DDH	39	53	6/33	33.3 ± 7.9	14	Crowe system	8 type I, 10type II, 12 type III, 23 type IV	39/39, 100%	22/22
	Control	24	48	4/20	31.5 ± 8.5					NA
Li 2013 [17]	DDH	75	114	NA	56 (23–78)	39	Hartofilakidis	64 type I, 2 type II, 8 type III	NA	22/21
	Control	36	36	NA	56 (23–78)	NA	NA	NA		NA
Li 2014 [16]	DDH	37	74	2/35	32.6 ± 8.1	14	Crowe system	5 type I, type II, type III, 4 type IV	7/37, 16.2%	22/22
	Control	37	74	2/35	32.3 ± 7.7	NA	NA	NA		NA
Imai 2018 [7]	DDH	29	29	0/29	35.8 8.8	NA	Crowe system	Type I subluxation	NA	21/21
	Control	48	48	0/48	54 10.8					NA
Hu 2019 [8]	DDH	116	196	19/97	21.6 ± 6.7	NA	LCE + FAA	116 (LCE < 20°+FAA < 40°), 80 (LCE < 20°+FAA > 40°)	NA	22/23
	Control	22	34	4/18	23.2 ± 6.8	NA	LCE + FAA	LCE > 20° and FAA < 40°		NA
Imai 2019 [6]	DDH	73	146	0/73	35.6 ± 9	73	Crowe system	Type II-IV subluxation	NA	21/22
	Control	45	90	0/45	49 ± 18.9	NA	NA	NA		NA
Peng 2022 [18]	DDH	70	86	18/52	27.1 ± 9.9	16	Hartofilakidis	Type I subluxation	6/70, 8.6%	21/22
	Control	33	33	15/18	35 ± 9.4	NA	NA	NA		NA
Fithian 2023 [19]	DDH	48	48	5/43	31.9 ± 8.4	NA	Hartofilakidis	Type I subluxation	8/48, 17%	21/21
	Control	48	48	5/43	30.6 ± 11.6	NA	NA	NA		NA

DDH, developmental dysplasia of the hip; AKP, anterior knee pain; LCE, lateral center-edge angle; FAA, femoral anteversion angle; NA, not available

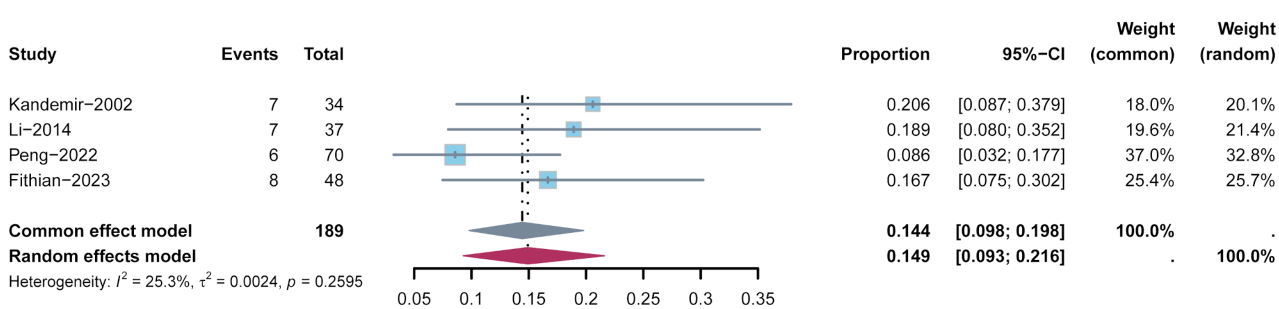

Fig. 2 Occasional anterior knee pain rate. Data pooled with a common effect model

$P < 0.0001$), decreased trochlear depth (weighted mean: 3.1 mm vs. 4.5 mm; WMD = -1.4 mm; $P < 0.0001$), and increased patellar tilt angle (weighted mean: 18.2° vs. 13.2°; WMD = 5.0°; $P < 0.0001$) (Fig. 6). Furthermore, one study indicated that the mean lateral shift of the patella (LSP) increased by approximately 2 mm in patients compared to the control group (5.1 mm vs. 3.8 mm, $P = 0.06$) [18], while another study found a significant increase in the proportion of patients with LSP > 5 mm (75/196 [38.3%] vs. 2/34 [5.9%], $P < 0.001$) [8].

Discussion

The most important finding of this meta-analysis and systematic review is that the developmental dysplasia of the hip leads to patellar malalignment and developmental changes in the bony anatomy of the knee joint, including the development of a valgus deformity of the lower extremity and trochlear dysplasia. These findings may be associated with patellar instability. In addition, the pooled rate of occasional anterior knee pain (AKP) was 14.4% in patients with neglected DDH.

Table 2 Measurement methods and changes in DDH knees of the significant knee parameters

Study	Measuring plane	Parameters	Image modality	Abbr.	Definition	Change in DDH knees
Kandemir 2002 [3]	Coronal plane	mechanical axis deviation	X-ray	MAD	distance from the center of the knee to the mechanical axis of lower extremity	Increase
	Coronal plane	lateral distal femoral angle	X-ray	LDFA	angle between the mechanical axis of the femur and joint orientation line of the distal part of the femur	Decrease
	Coronal plane	medial proximal tibial angle	X-ray	MPTA	angle between the mechanical axis of the tibia and joint orientation line of the proximal part of the tibia	Decrease
	Coronal plane	horizontal dimension of the MFC	X-ray	HDMFC	distances from the anatomic axis of the femur to the most medial point of the medial femoral condyle	Decrease
	Coronal plane	horizontal dimension of the LFC	X-ray	HDLFC	distances from the anatomic axis of the femur to the most medial point of the lateral femoral condyle	Decrease
	Coronal plane	vertical dimension of the MFC	X-ray	VDMFC	distances from the line perpendicular to the femoral anatomic axis at the tip of the intercondylar notch to the most distal points of the medial femoral condyles	Increase
	Coronal plane	vertical dimension of the LFC	X-ray	VDLFC	distances from the line perpendicular to the femoral anatomic axis at the tip of the intercondylar notch to the most distal points of the lateral femoral condyles	Increase
	Transverse plane	femoral anteversion	CT	FAA	angle between femoral neck axis and posterior bicondyle line	Increase
	Transverse plane	sulcus angle	CT	SA	angle among most anterior points on the medial and lateral facets and the deepest point in the trochlear groove	Increase
Akşahin 2012 [10]	Transverse plane	sulcus angle	CT	SA	as described above	Increase
	Transverse plane	patellar tilt angle	CT	PTA	angle between the coronal axis of the patella and a line tangent to the medial and lateral trochlear ridges	Increase
	Transverse plane	Lateral shift of patella	CT	LSP	distance between perpendicular line from the apex of the MFC to tangent line of the posterior condyle and perpendicular line from the patella medial edge to the tangent line of the posterior condyle	Increase
Li 2013 [17]	Transverse plane	femoral anteversion	CT	FAA	as described above	Increase
	Transverse plane	anteroposterior diameter of MFC	CT	APMFC	anteroposterior diameter of the medial femoral condyle	Decrease
	Transverse plane	anteroposterior diameter of LFC	CT	APLFC	anteroposterior diameter of the lateral femoral condyle	Decrease
	Transverse plane	condyle asymmetry	CT	CA	APLFC/APMFC	Decrease
	Transverse plane	width of femoral condylar	CT	WFC	width of femoral condylar	Decrease
	Transverse plane	patellar tilt angle	CT	PTA	as described above	Increase
Li 2014 [16]	Coronal plane	horizontal dimension of the LFC	X-ray	HDLFC	as described above	Decrease
	Coronal plane	vertical dimension of the MFC	X-ray	VDMFC	as described above	Increase
	Coronal plane	vertical dimension of the LFC	X-ray	VDLFC	as described above	Decrease
	Coronal plane	horizontal dimension of the MFC	X-ray	HDMFC	as described above	Increase
	Coronal plane	lateral distal femoral angle	X-ray	LDFA	as described above	Decrease

Table 2 (continued)

Study	Measuring plane	Parameters	Image modality	Abbr.	Definition	Change in DDH knees
Imai 2018 [7]	Transverse plane	femoral anteversion	CT	FAA	as described above	Increase
	Transverse plane	knee rotation angle	CT	TRA	angle between the tibial anteroposterior axis and the line perpendicular to the clinical epicondylar axis	Increase
Hu 2019 [8]	Coronal plane	quadriceps angle	X-ray	QA	angle between a line drawn from the cranial lip of the acetabulum to the center of the patella and a line from the center of the patella to the center of the tibial tuberosity	Increase
	Transverse plane	femoral anteversion	CT	FAA	as described above	Increase
	Transverse plane	patellar tilt angle	CT	PTA	as described above	Increase
	Transverse plane	sulcus angle	CT	SA	as described above	Increase
	Transverse plane	lateral shift of patella	CT	LSP	as described above	Increase
Imai 2019 [6]	Transverse plane	femoral anteversion	CT	FAA	as described above	Increase
	Transverse plane	knee rotation angle	CT	TRA	as described above	Increase
	Transverse plane	anteroposterior diameter of MFC	CT	APMFC	as described above	Decrease
	Transverse plane	condyle asymmetry	CT	CA	APLFC/APMFC	Decrease
Peng 2022 [18]	Transverse plane	sulcus angle	CT	SA	as described above	Increase
	Transverse plane	femoral trochlear depth	CT	FTD	distance from the deepest point of the femoral trochlear groove to the line connecting the most anterior points on the medial and lateral femur condyles	Decrease
	Transverse plane	lateral shift of patella	CT	LSP	as described above	Increase
	Transverse plane	patellar tilt angle	CT	PTA	as described above	Increase
Fithian 2023 [19]	Transverse plane	femoral trochlear depth	MRI	FTD	difference between the mean height of the cartilaginous facets and the height of the cartilaginous groove relative to the posterior condylar axis.	Decrease

MFC, medial femoral condyle; LFC, lateral femoral condyle; CT: computed tomography; MRI, magnetic resonance imaging; NA, not available

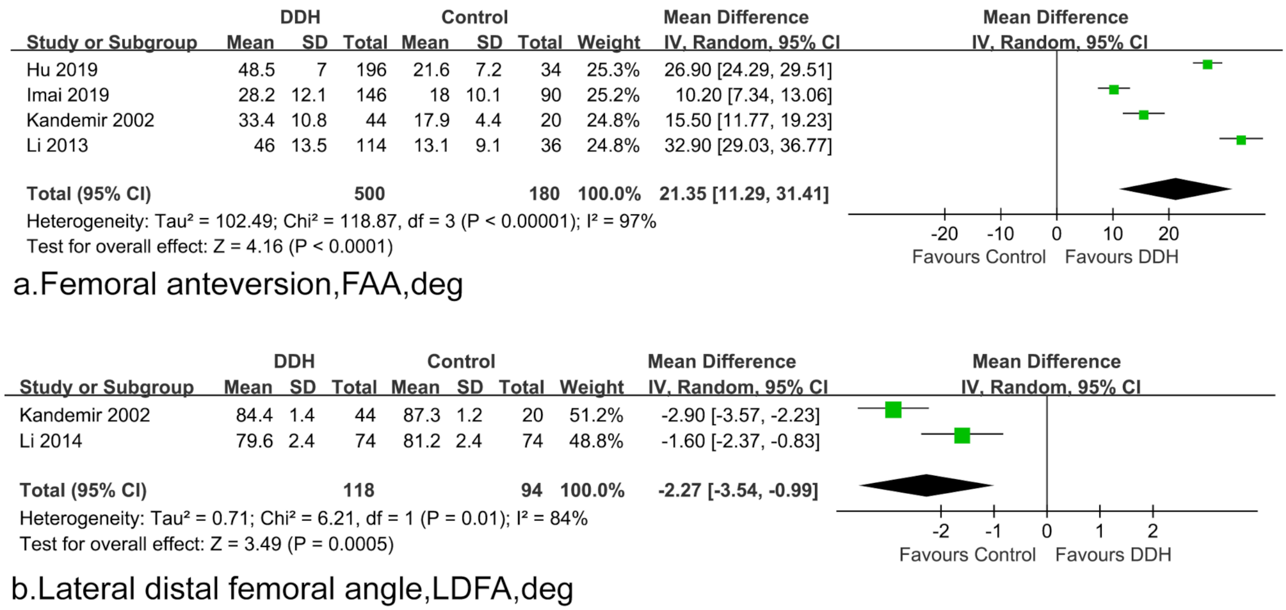

Fig. 3 The differences in femoral anteversion and lateral distal femoral angle between the developmental dysplasia of the hip and control groups

The morphology of the patellofemoral joint (PFJ) is a critical factor influencing patellar tracking and stability [17, 20, 21]. Patellofemoral malalignment can result from three primary factors: ligamentous laxity, asymmetric chondral destruction, and structural osseous deformity [3]. Compared to the control group, patients with neglected DDH exhibited no significant differences in knee stability [3, 16, 18, 19], which may suggested similar soft tissue conditions between two populations. In the absence of soft tissue abnormalities, abnormal bony development of the knee joint is the primary cause of osseous malalignment. This meta-analysis found that DDH patients demonstrate a reduced LDFA, hypoplasia in the horizontal dimension of the LFC, and a reduced anteroposterior diameter of the MFC, but with a significant increase in vertical dimension of the MFC. In addition to influencing osteotomy planning during total knee arthroplasty [6, 22], these bony abnormalities have been shown to lead to valgus malalignment of the lower limb, which in turn affects patellofemoral congruence [3, 10] and patellar positioning [17, 23]. Furthermore, this study also revealed that patients with neglected DDH exhibit more pronounced torsional deformities of the lower limbs compared to controls, specifically with increased femoral torsion and knee torsion, while tibial torsion showed no significant changes. These torsional deformities have been shown to be closely associated with patellar instability [24–28].

The pathogenic factors and mechanisms of femoral trochlear dysplasia remain controversial. Genetic associations with DDH [29–32] and emerging genomic technologies [33] inform our understanding of musculoskeletal development. In addition to genetic factors, some studies proposed that mechanical stress in the PFJ is a direct determinant of normal trochlear development. Animal model studies have shown that abnormal PFJ mechanical stress caused by patellar dislocation can contribute to trochlear dysplasia [34–36]. Tardieu and Dupont observed that as children begin

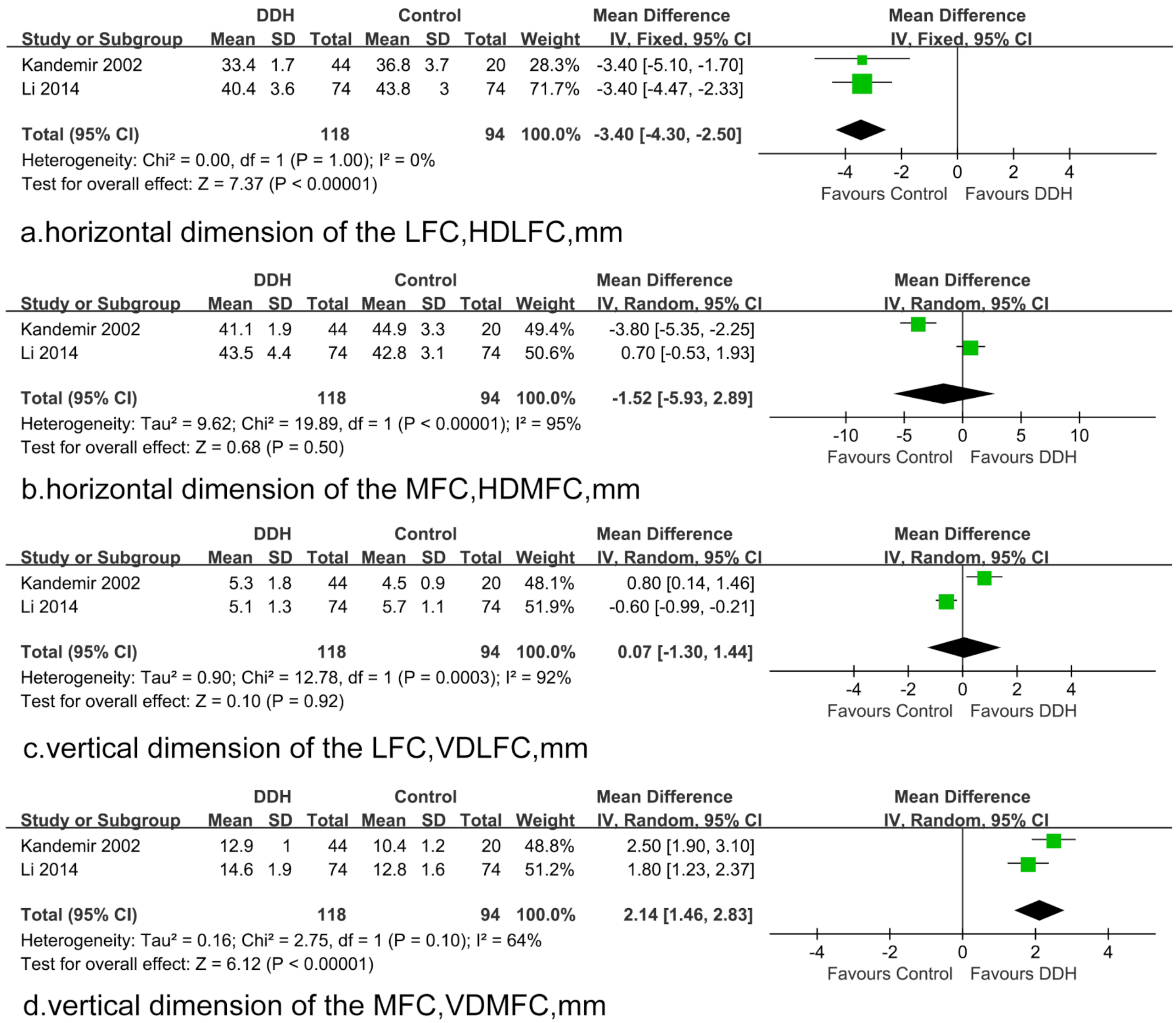

Fig. 4 The differences in the coronal plane dimension of the femoral condyles between the developmental dysplasia of the hip and control groups

to walk, the femoral obliquity angle gradually forms, leading to secondary valgus of the knee extensor mechanism. This process deepens the trochlear groove and promotes the development of the lateral femoral condyle. However, this phenomenon was not observed in children who were unable to walk normally [37]. Recent studies [5] have identified the morphology of the medial epiphyseal plate and the trochlea-epiphysis distance as significant risk factors for trochlear dysplasia, both of which are associated with clinical outcomes.They also found that correcting abnormal PFJ stress in immature patients can significantly improve both epiphyseal plate and trochlear development. These findings underscore the close relationship between epiphyseal plate stress and trochlear development. Importantly, previous studies have suggested that hip adduction contracture caused by DDH may impair the development of the distal femoral

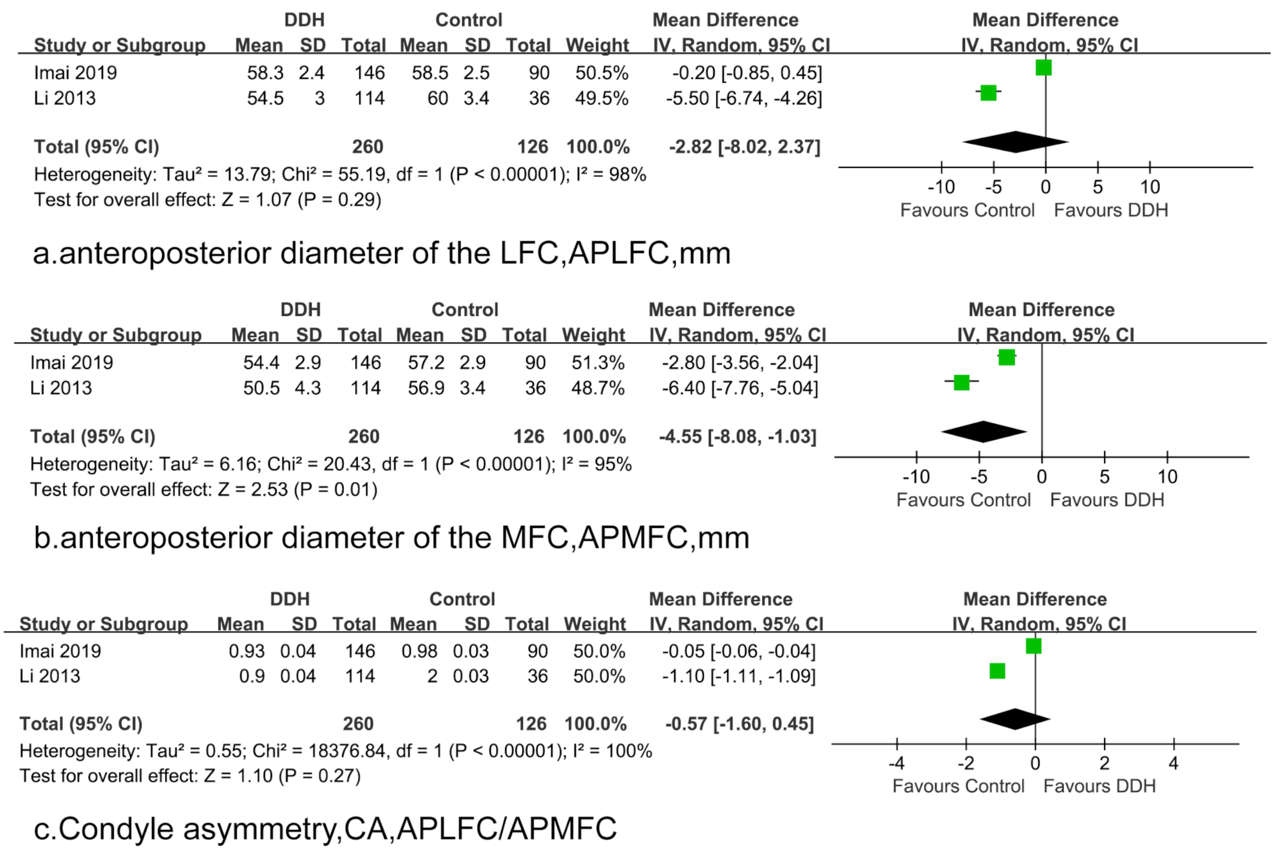

Fig. 5 The differences in the transverse plane dimension of the femoral condyles between the developmental dysplasia of the hip and control groups

epiphyseal plate [3]. This could explain the findings in the present study, where patients with neglected DDH exhibited increased sulcus angles and decreased trochlear depth, both of which are characteristic features of trochlear dysplasia.

Patellar instability is a common cause of anterior knee discomfort associated with patellofemoral osteoarthritis or chondromalacia patellae [38]. Patellar malalignment impair the balance of the surrounding soft tissue structures, making the patella prone to subluxation or dislocation even during daily sports activity. Fulkerson et al. [39] identified abnormal patellar tilt as one type of patellar instability. The findings of this meta-analysis indicated that in patients with neglected DDH, the patellar tilt angle and lateral shift of the patella were significantly higher than those in the control group, which may ultimately lead to patellar instability. These results highlight the importance for surgeons to pay additional attention to the developmental status of the hip joint when managing patellar instability.

This study has limitations. First, the search strategy contained bias due to the possibly unavoidable missing of relevant studies. However, four main databases were searched to include all the relative studies comparing the morphological parameters of the knee between DDH patients and healthy individuals. Second, significant heterogeneities were found in the comparison of structural variables between groups. This may be related to differences in the measurements, ethnicity of the subjects, the classification of DDH, and the affected side. The results of the analysis were carefully interpreted. Third, the participants included in these studies were limited, and the analysis was restricted to comparisons of a finite set of bony structural parameters, which may not fully elucidate the overall knee morphology. Future studies could leverage advanced image processing methods to analyze the comprehensive knee morphology.

Conclusion

Developmental dysplasia of the hip leads to patellar malalignment and developmental changes in the bony anatomy of the knee joint, including the development of a valgus deformity of the lower extremity and trochlear dysplasia. These findings may be associated

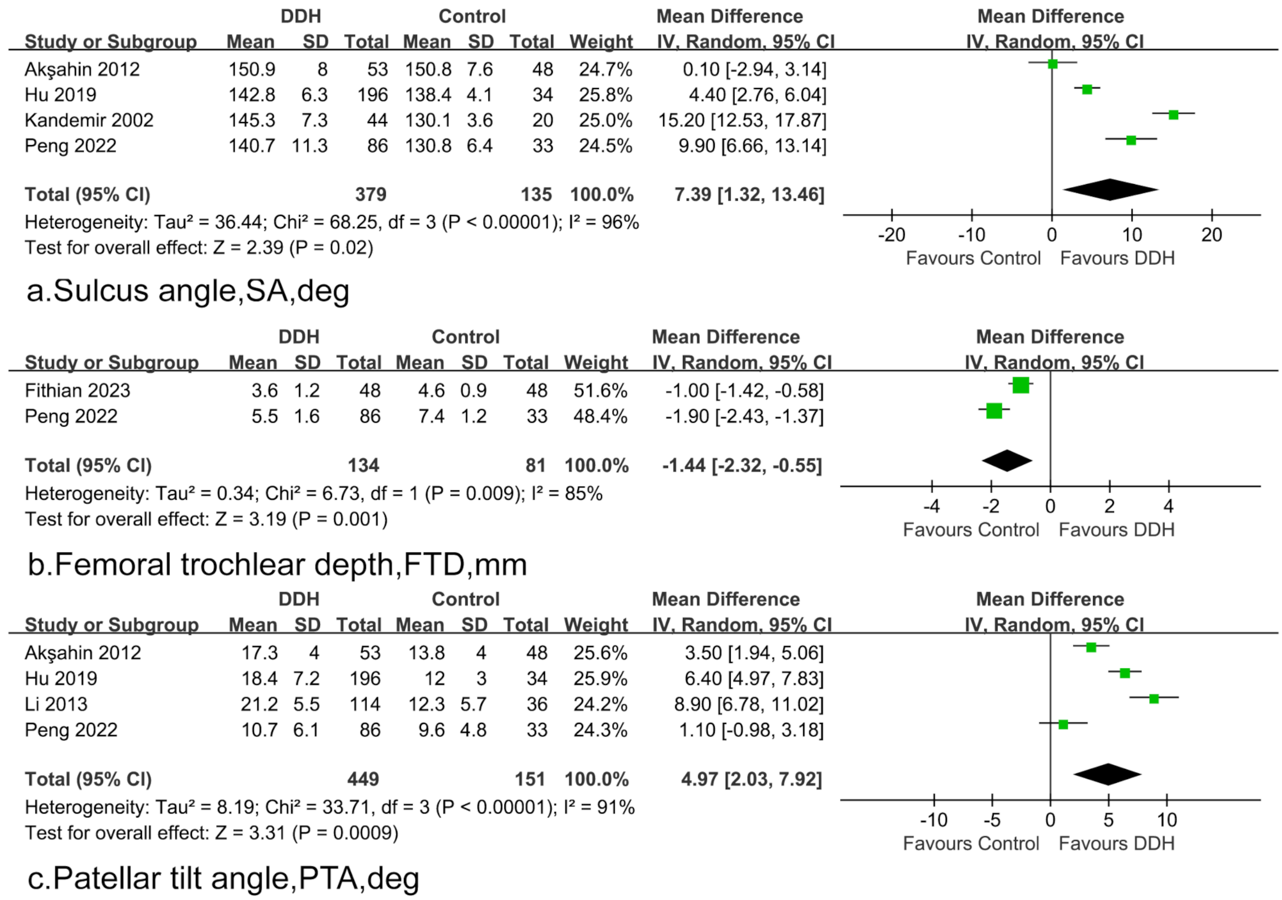

Fig. 6 The differences in bony structures of the trochlear and patella between the developmental dysplasia of the hip and control groups

with patellar instability. In the clinical management of patellar instability, hip morphology should be evaluated to assess the condition and guide treatment.

Abbreviations

DDH	developmental dysplasia of the hip
AKP	Anterior knee pain
PFJ	Patellofemoral joint
MFC	Medial femoral condyle
LFC	Lateral femoral condyle
SA	Sulcus angle
FTD	Femoral trochlear depth
PTA	Patellar tilt angle
FAA	Femoral anteversion angle
LDFA	Lateral distal femoral angle

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-025-05877-y.

Supplementary Material 1

Acknowledgements

No.

Author contributions

Hui Zhang: Conceptualization and study design; Daofeng Wang: data collection, analysis; and original manuscript writing; Jianzhong Sun and Yang Liu: data analysis and manuscript revision; Zhengjie Tang and Jianzhong Sun: Language check, review & editing. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding

This study was supported by the National Natural Science Foundation of China (82472527), and Beijing Municipal Science & Technology Commission (No. Z211100002921043 and No. Z221100007422004). We declare that no funds, grants, or other support were received during the preparation of this manuscript.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

PROSPERO registration number
CRD42025640292.

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Received: 20 February 2025 / Accepted: 30 April 2025
Published online: 20 May 2025

References

1. Wedge JH, Wasylenko MJ. The natural history of congenital disease of the hip. J Bone Joint Surg Br. 1979;61–b:334–8.
2. Crawford AH, Mehlman CT, Slovek RW. The fate of untreated developmental dislocation of the hip: long-term follow-up of eleven patients. J Pediatr Orthop. 1999;19:641–4.
3. Kandemir U, Yazici M, Alpaslan AM, Surat A. Morphology of the knee in adult patients with neglected developmental dysplasia of the hip. J Bone Joint Surg Am. 2002;84:2249–57.
4. Wedge JH, Wasylenko MJ. The natural history of congenital dislocation of the hip: a critical review. Clin Orthop Relat Res. 1978;154:62.
5. Hao K, Li Z, Wang J, Huo Z, Niu Y, Wang F. Morphological improvement of the epiphyseal plate and trochlea after surgical correction in skeletally immature patients with patellar dislocation and trochlear dysplasia. Am J Sports Med. 2025;3635465241301775.
6. Imai N, Miyasaka D, Hirano Y, Suzuki H, Tsuchiya K, Endo N. Tibiofemoral rotation is related to differences in the lateral femoral condyle configuration in both normal subjects and women with hip dysplasia: a three-dimensional analysis. BMC Musculoskelet Disord. 2019;20:353.
7. Imai N, Miyasaka D, Suzuki H, Tsuchiya K, Ito T, Minato I, et al. The anteroposterior axis of the tibia is adjusted to approximately a right angle to the anterior pelvic plane in the standing position in patients with hip dysplasia similar to normal subjects: a cross-sectional study. J Orthop Surg Res. 2018;13:105.
8. Hu B, Sang L, Gao D, Wu Y, Zhang H, Luo D. Patella alignment abnormality in patients with developmental dysplasia of the hip. J Orthop Surg (Hong Kong). 2019;27:2309499019854039.
9. Hasegawa Y, Iwata H. Natural history of unreduced congenital dislocation of the hip in adults. Arch Orthop Trauma Surg. 2000;120:17–22.
10. Akşahin E, Güzel A, Erdoğan AO, Yüksel HY, Celebi L, Aktekin CN, et al. The patellofemoral kinematics in patients with untreated developmental dislocation of the hip suffering from patellofemoral pain. Knee Surg Sports Traumatol Arthrosc. 2012;20:2337–47.
11. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Int J Surg. 2021;88:105906.
12. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg. 2003;73:712–6.
13. Wang D, Li J, Xu G, Zhang H, Xu C, Zhang W, et al. Morphometric feature description of the proximal ulna based on quantitative measurement: a key consideration for implant design. Surg Radiol Anat. 2023;45:215–24.
14. Luo D, Wan X, Liu J, Tong T. Optimally estimating the sample mean from the sample size, median, mid-range, and/or mid-quartile range. Stat Methods Med Res. 2018;27:1785–805.
15. Wan X, Wang W, Liu J, Tong T. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. BMC Med Res Methodol. 2014;14:135.
16. Li Q, Kadhim M, Zhang L, Cheng X, Zhao Q, Li L. Knee joint changes in patients with neglected developmental hip dysplasia: a prospective case-control study. Knee. 2014;21:1072–6.
17. Li H, Qu X, Wang Y, Dai K, Zhu Z. Morphological analysis of the knee joint in patients with hip dysplasia. Knee Surg Sports Traumatol Arthrosc. 2013;21:2081–8.
18. Peng J, Xiao F, Zhu J, Shen C, Li Y, Han X, et al. Characteristics of the patellofemoral joint of patients with DDH and the effects of Bernese periacetabular osteotomy on the patellofemoral joint. BMC Musculoskelet Disord. 2022;23:337.
19. Fithian AT, Richey AE, Sherman SL, Shea KG, Pun SY. Association of hip dysplasia with trochlear dysplasia in skeletally mature patients. Orthop J Sports Med. 2023;11:23259671231200805.
20. Stäubli HU, Dürrenmatt U, Porcellini B, Rauschning W. Anatomy and surface geometry of the patellofemoral joint in the axial plane. J Bone Joint Surg Br. 1999;81:452–8.
21. Dejour DH, de Sanctis EG, Müller JH, Deroche E, Pineda T, Guarino A et al. Adapting the dejour classification of trochlear dysplasia from qualitative radiograph- and CT-based assessments to quantitative MRI-based measurements. Knee Surg Sports Traumatol Arthrosc. 2024.
22. Berger RA, Rubash HE, Seel MJ, Thompson WH, Crossett LS. Determining the rotational alignment of the femoral component in total knee arthroplasty using the epicondylar axis. Clin Orthop Relat Res. 1993;40– 7.
23. Shih YF, Bull AM, Amis AA. The cartilaginous and osseous geometry of the femoral trochlear groove. Knee Surg Sports Traumatol Arthrosc. 2004;12:300–6.
24. Wang D, Zhang Z, Cao Y, Song G, Zheng T, Di M, et al. Recurrent patellar dislocation patients with high-grade J-sign have multiple structural bone abnormalities in the lower limbs. Knee Surg Sports Traumatol Arthrosc. 2024;32:1650–9.
25. Zhang Z, Zhang H, Song G, Zheng T, Ni Q, Feng H. Increased femoral anteversion is associated with inferior clinical outcomes after MPFL reconstruction and combined tibial tubercle osteotomy for the treatment of recurrent patellar instability. Knee Surg Sports Traumatol Arthrosc. 2020;28:2261–9.
26. Zhang ZJ, Dimeng LQ, Cao YW, Zheng T, Song GY, Li Y, et al. Predictors of graft failure after primary medial patellofemoral ligament reconstruction. Orthop J Sports Med. 2022;10:23259671221138854.
27. Wang D, Liu Y, Sun J, Fu Q, Lv C, Yue T et al. Patients with jumping sign exhibit rotational and bony structural abnormalities consistent with high-grade J-sign in recurrent patellar dislocation. Knee Surg Sports Traumatol Arthrosc. 2025.
28. Wang D, Zheng T, Cao Y, Zhang Z, Di M, Fu Q, et al. Derotational distal femoral osteotomy improves subjective function and patellar tracking after medial patellofemoral ligament reconstruction in recurrent patellar dislocation patients with increased femoral anteversion: A systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2024;32:151–66.
29. Glard Y, Jouve JL, Garron E, Adalian P, Tardieu C, Bollini G. Anatomic study of femoral patellar groove in fetus. J Pediatr Orthop. 2005;25:305–8.
30. Glard Y, Jouve JL, Panuel M, Adalian P, Tardieu C, Bollini G. An anatomical and biometrical study of the femoral trochlear groove in the human fetus. J Anat. 2005;206:411–3.
31. Ghosh S, Fryer AA, Hoban PR, Wynn-Jones C, Maffulli N. Fibrillin 1 gene with R2726W mutation is absent in patients with primary protrusio acetabuli and developmental dysplasia of the hip. Med Sci Monit. 2009;15:Cr199–202.
32. Kapoor B, Dunlop C, Wynn-Jones C, Fryer AA, Strange RC, Maffulli N. Vitamin D and oestrogen receptor polymorphisms in developmental dysplasia of the hip and primary protrusio acetabuli–a preliminary study. J Negat Results Biomed. 2007;6:7.
33. Aicale R, Tarantino D, Maccauro G, Peretti GM, Maffulli N. Genetics in orthopaedic practice. J Biol Regul Homeost Agents. 2019;33:103–17. XIX Congresso Nazionale S.I.C.O.O.P. Societa' Italiana Chirurghi Ortopedici Dell'ospedalita' Privata Accreditata.
34. Huri G, Atay OA, Ergen B, Atesok K, Johnson DL, Doral MN. Development of femoral trochlear groove in growing rabbit after patellar instability. Knee Surg Sports Traumatol Arthrosc. 2012;20:232–8.
35. Wang S, Ji G, Yang X, Wang X, Wang R, Li M, et al. Femoral trochlear groove development after patellar subluxation and early reduction in growing rabbits. Knee Surg Sports Traumatol Arthrosc. 2016;24:247–53.
36. Li W, Wang Q, Wang F, Zhang Y, Ma L, Dong J. Femoral trochlear dysplasia after patellar dislocation in rabbits. Knee. 2013;20:485–9.
37. Tardieu C, Dupont JY. [The origin of femoral trochlear dysplasia: comparative anatomy, evolution, and growth of the patellofemoral joint]. Rev Chir Orthop Reparatrice Appar Mot. 2001;87:373–83.
38. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: an anatomic radiographic study. Knee Surg Sports Traumatol Arthrosc. 1994;2:19–26.
39. Fulkerson JP, Shea KP. Disorders of patellofemoral alignment. J Bone Joint Surg Am. 1990;72:1424–9.

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