

Is the Fibula High in Children and Adolescents with Discoid Lateral Meniscus?

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Abstract

Background A high fibular location on plain radiographs has been considered suggestive of a discoid lateral meniscus (DLM). We sought to determine whether the high location of the fibular head observed in DLM patients represents a true pathologic finding.

Methods Eighty-two patients with symptomatic DLM who underwent arthroscopic treatment constituted the study group (DLM group). The same number of age-matched patients without DLM (control group) were recruited. The DLM group was further divided according to the presence or absence of a knee extension block (EB) of more than 10 degrees into EB(+) and EB(-) subgroups. We defined the compensated distance to the fibular head (CDF) as the distance from the lateral joint line to the tip of the fibular head divided by the femoral condylar width. CDF values measured on anteroposterior (AP) plain radiographs and sagittal MR images were compared between the DLM and control groups and between the EB(+) and EB(-) subgroups.

Results There was no significant difference in the mean preoperative CDF value on either AP plain radiographs or sagittal MR images between the DLM and control groups. However, the mean CDF value on AP plain radiographs was significantly lower in the EB(+) subgroup than in the EB(-) subgroup ($p = 0.011$). The knee EB disappeared in all patients after arthroscopic treatment when the CDF on AP plain radiographs showed no significant difference between subgroups ($p > 0.05$). Linear regression analysis revealed that the CDF on AP plain radiographs decreased significantly when knee flexion was increased from 0 to 30 degrees ($p = 0.003$).

Conclusions The high fibular location observed on AP plain radiography in DLM patients was associated with limited knee extension. Altered X-ray beam projection to the flexed knee creates the false appearance of a high fibular location on AP plain radiography.

Background

Discoid lateral meniscus (DLM) is a well-known anatomic variant of the knee with a reported prevalence ranging from 5% in Caucasians to 17% in Asians.^{1,2} The diagnosis of DLM is based on the patient's symptoms, physical examinations, and findings of various imaging modalities including plain radiography, ultrasonography, and magnetic resonance imaging (MRI).³ Traditionally, a high fibula, widening of the lateral joint space, flattening of the lateral femoral condyle, cupping of the lateral tibial plateau, and a hypoplastic lateral tibial spine have been considered to be signs suggestive of DLM on plain radiography.^{1,4-7} Most of these radiographic signs are explained by secondary changes to the articular surface caused by mechanical compression from the thick meniscal tissue,^{7,8} though investigations of the etiology of a high fibular head location are scarce.

The current authors have observed that the finding of a high fibular location on plain radiographs often disappears after arthroscopic treatment, especially when patients present preoperatively with limited knee

extension. This led us to investigate the pathomechanism of a high fibula in DLM. The purpose of this study was to determine whether a high location of the fibular head observed in patients with DLM represents a true pathologic finding or a mere apparent observation associated with the position of the knee during the radiographic examination. We hypothesized that extension limitations of the affected knee and the subsequent oblique beam projection during anteroposterior (AP) projection plain radiographic examination would produce a false image showing a high location of the fibular head.

Methods

Subjects

This retrospective case-control study was approved by the Institutional Review Board of our institute. The patients with DLM who underwent arthroscopic treatment in a tertiary children's hospital from July 2003 to September 2013 were the subjects of the study. The inclusion criteria were patients 1) with DLM confirmed by arthroscopic findings, 2) aged 6 years or older to ensure ossification of the fibular head that could be evaluated on plain radiographs, and 3) who underwent preoperative and follow-up plain radiographs with anteroposterior and lateral projections as well as preoperative MRI. The patients with bilateral involvement, discoid medial meniscus, underlying conditions that might affect skeletal growth, and history of previous fracture around the knee were excluded. The patients with DLM constituted the study group (DLM group), and the same number of age-matched patients without DLM (control group) were randomly selected from the patients with plain radiographs and MRIs during the same study period. The DLM group was further divided according to the preoperative presence or absence of a knee extension block (EB) of more than 10 degrees into EB(+) and EB(-) subgroups. The presence of knee EB was evaluated based on medical records. Physical exam and knee radiographs exam were performed in all patients on the same day. Patients with limited knee extension were not included in the control group.

Measurements

The fibular head was considered to be located "high" when the distance from the proximal tibial physis to the proximal fibular physis was less than 5 mm on AP plain radiographs, in accordance with the normal fibular height in growing children observed in a previous study.⁹ The distance from the lateral joint line to the tip of the fibular head was preoperatively measured on AP plain radiographs and sagittal MR images, and the measurement was then repeated using AP plain radiography at the final follow-up. The joint line was defined as the bisected line between the ossified part of distal femur condyle and proximal tibia. The distance measured on sagittal MR image was selected as the shortest distance between the lateral joint line and the cartilaginous tip of the fibular head among the several sagittal MR images. We defined the compensated distance to the fibular head (CDF) as the distance from the lateral joint line to the tip of the fibular head divided by the femoral condylar width. The CDF was calculated and used to compensate for the individual variability of knee size in growing children (Fig. 1).

All measurements were performed on PACS monitors (Picture Archiving and Communications System; Infinitt Healthcare) using a mouse-point cursor and an automated computer calculation for the distance.

Two observers measured the values independently, and the average values were used for analysis. Intraobserver reliability was checked by repeated measurements using 30 randomly selected radiographs of the patients with a four-week interval. Interobserver reliability was calculated using the first session of measurements from the two observers.

Statistical analysis

A power analysis was performed to determine whether the sample size of the current study population would be adequate to detect the differences of one standard deviation in the CDF between the comparison groups. The intraclass correlation coefficient (ICC) with single measure and absolute agreement type and a two-way mixed effect model were used to determine the reliability of the tests using continuous variables.

The mean CDF measured on AP plain radiographs and sagittal MR images in the DLM group was compared to that in the control group, and the measured values were further compared between the EB(+) and EB(-) subgroups of the DLM group. The analysis of variance (ANOVA) was used to analyze differences in the CDF between the DLM and control groups and between the EB(+) and EB(-) subgroups. Individual comparisons were conducted using the post hoc Bonferroni method. The Chi square test was used for a trend analysis to compare the proportion of categorical variables between the groups. The Student t-test was performed to compare the means of two independent variables, and the paired t-test was used to compare the means of two related variables. Linear regression analysis was used to evaluate a change trend of the CDF on AP radiography with increased knee flexion. The statistical analysis was performed with the SPSS software (ver. 21.0; IBM, Chicago, Illinois). A p-value less than 0.05 was considered statistically significant.

Results

Demographic characteristics

A total of 126 patients (143 knees) with DLM underwent arthroscopic treatment from July 2003 to September 2013. The study group (DLM group) comprised 82 patients (35 boys and 47 girls, 82 knees) after the exclusion of 44 patients with bilateral involvement of DLM (34 knees of 17 patients), discoid medial meniscus (3 knees of 3 patients), underlying conditions that might affect growth around the knee joint (8 knees of 8 patients with skeletal dysplasia, myelodysplasia, juvenile idiopathic arthritis, septic arthritis, and hypophosphatemic rickets), and a history of previous fracture around the knee (3 knees of 3 patients), as well as those aged less than 6 years (13 knees of 13 patients). The size of the study population was considered adequate, with a sample size of 37 patients per group demonstrating 90% power and a 5% two-tailed type I error rate to detect differences in the CDF. In the DLM group, 43 patients (52%, 43 of 82) presented with a greater than 10-degree knee EB, thereby designating the EB(+) subgroup (n=43) and the EB(-) subgroup (n=39). The control group comprised 82 patients (49 boys and 33 girls, 82 knees) with a non-discoid meniscus. They underwent MRI to evaluate the cartilaginous articular surface, ligaments, and meniscus in the context of trauma other than fracture (n=43), pain without pathologic

findings (n=30), and transient inflammation (n=9). The mean age of the DLM group at the time of MRI evaluation (11.0 years; range, 6 to 18 years) was not significantly different from that in the control group (12.4 years; range, 6 to 18 years) ($p=0.060$). The age of the patients in the EB(+) and EB(-) subgroups was also not different, at 9.7 ± 2.9 years and 11.2 ± 4.4 years, respectively ($p=0.081$).

Comparisons of the DLM group vs. the control group

The interobserver ICC for each measurement ranged from 0.731 to 0.989, indicating a significantly high agreement between the evaluators. The intraobserver ICC ranged from 0.905 to 0.990 for each parameter, also indicating a significantly high agreement (Table 1).

The mean preoperative CDF on AP plain radiography was slightly shorter in the DLM group (0.182, 95% CI 0.171 – 0.193) than in the control group (0.187, 95% CI 0.176 – 0.196), but the difference was not statistically significant ($p=0.503$). The mean CDF on sagittal MR images in the DLM group (0.169, 95% CI 0.158 – 0.180) was similar to that in the control group (0.177, 95% CI 0.170 – 0.188) ($p=0.250$, Table 2). The prevalence of a true high fibular position based on sagittal MR images in the DLM group (17/82 patients; 21%) was also similar to that in the control group (13/82 patients; 16%) ($p=0.545$).

Comparison of the EB(+) and EB(-) subgroups of the DLM group

The mean preoperative CDF on the AP plain radiographs was significantly shorter in the EB(+) group (0.160 ± 0.052) than in the EB(-) group (0.192 ± 0.045) ($p=0.006$), whereas the mean preoperative CDF on sagittal MR images in the EB(+) group (0.196, 95% CI 0.180 – 0.211) did not significantly differ from that in the EB(-) group (0.206, 95% CI 0.190 – 0.222) ($p=0.549$) (Figure 2).

Postoperatively (mean follow-up 7.7 years, range 5.0 to 13.9), knee EB disappeared in all EB(+) patients and the mean CDF on the AP plain radiographs in these patients did not significantly differ from that in the EB(-) group ($p=0.557$) (Table 2). Linear regression analysis revealed that the measured CDF decreased significantly when knee flexion was increased from 0 to 30 degrees on knee AP plain radiographs ($p=0.003$) (Figure 3).

Discussion

Plain radiographic findings of knees with DLM typically show widening of the lateral joint space, increased obliquity of the lateral tibial plateau, and increased concavity or cupping of the underlying tibial plateau.^{4,7,10-12} These findings may be secondary to the increased cephalocaudal dimension of the discoid meniscus.¹³ A high fibular head has also been reported as a significant finding of DLM in some studies,^{4,7} although others^{2,14} believe plain radiography has little value in the diagnosis of DLM. Choi and colleagues⁴ reported that a high fibular head was observed more frequently in children with DLM aged 4

to 15 years than in an age-matched cohort without DLM. Kim and colleagues⁷ reported that a high fibula and widened lateral joint space were the only significant findings on plain radiography in adult knees with DLM, while the other radiographic findings such as the height of the lateral tibial spine, cupping of the lateral tibial condyle, notching of the lateral femoral condyle, and squaring of the lateral femoral condyle were not significant. While a high fibula may certainly be observed in knees with DLM, its pathomechanism has not been discussed in the literature except in a study by Burman and Neustadt¹⁵ in 1950 that reported five cases of torn DLM, among which two showed a high fibular head on plain radiography. The authors postulated that DLM was a congenital defect among a series of possible defects in the fibular half of the lower leg including a high fibular head, peroneal tendon subluxation at the ankle, peroneal muscle deficiency, and altered shape of the lateral malleolus. They stated that all such defects result from failure of normal regression in the early embryonic period. However, no subsequent studies have demonstrated that DLM develops mainly in association with other congenital defects of the fibular half of the lower leg. Our study further suggests that a high fibular position may not actually represent a true pathologic change but a false radiographic observation associated with temporarily limited knee extension before treatment.

When AP plain radiography of the knee joint is conducted, an X-ray beam is projected perpendicular to the axis of the tibia and fibula as well as the radiography cassette. However, the beam projection changes to the cephalocaudal direction in relation to the axis of the tibia and fibula, while remaining perpendicular to the cassette, when the knee cannot be extended fully. The altered beam projection to the flexed knee produces a distorted image with a seemingly high fibular head (Fig. 4). To ensure the accuracy of this explanation, we conducted an additional experimental study using a cadaver. The results support our explanation (Fig. 5).

Among our patients, 55% (43/82) of the DLM group presented with a knee EB of more than 10 degrees and 21% (17/82) showed a high fibular position based on Ogden's criteria.⁹ The CDF value on AP plain radiographs in the EB(+) subgroup was significantly smaller (high fibular position) than that in the EB(-) subgroup. However, the CDF values measured on sagittal MR images, which are not affected by the knee flexion position, were similar regardless of the presence or absence of knee EB. The CDF values of the EB(+) knees increased and became similar to the values of EB(-) knees postoperatively, when the knee EB disappeared after arthroscopic treatment. We further demonstrated a decrease in CDF when knee flexion was increased from 0 to 30 degrees. These results indicate that the high fibular location on preoperative AP plain radiography may be a false sign caused by limited knee extension. Knee EB in patients with DLM is a common clinical manifestation along with pain, with a reported prevalence varying from 6–67%.^{16–20} Yoo and colleagues²⁰ and Ahn and colleagues¹⁸ suggested that the mechanisms of knee EB in DLM were anteriorly impinged DLM due to instability with or without tear, pain associated with synovitis, and thick anterior meniscal tissue. This clinical manifestation usually resolves after arthroscopic treatment with stretching exercises at home. A study by Katsui and colleagues²¹ examined the effect of the X-ray beam projection angle on plain radiographic images of the ankle joint. They reported that the angle between the distal one-third of the tibial shaft and the line connecting both malleolar tips changed

according to different X-ray beam projection angles. We believe that these changes occur because the projected two-dimensional image of a three-dimensional structure may be distorted depending on the position of the structure or the X-ray beam projection angle.

Limitations

The present study has some limitations. First, our study cohort does not represent the general population with DLM, because we investigated symptomatic patients who underwent arthroscopic treatment. More than half of our patients showed preoperative knee EB. Second, although we excluded pathologic conditions that might affect physal growth around the knee, the patients in the control group were not recruited from a healthy population but from patients who underwent MRI for various reasons. However, we did not use the contralateral knees as the control group because the rate of bilaterality is reportedly as high as 79–97% in Asian patients who underwent arthroscopic surgery.^{22,23} At the time of designing this study, prior to determining whether or not the high fibular position was in fact a true pathologic finding associated with DLM, it was not appropriate to use the contralateral knee as the control. Despite these limitations, a strength of this study is that it is the first to have investigated the possible pathomechanism of a high fibular position in DLM by comparing patients with DLM with an age-matched control group using plain radiography and MRI.

Conclusion

While we observed a high fibular location in 21% of the knees with DLM, the prevalence was not significantly different from that in the control group. The high fibular location observed on AP plain radiography in DLM patients was associated with limited knee extension, which resulted in an altered X-ray beam projection to the flexed knee and the appearance of a high fibular location.

Abbreviations

DLM: Discoid lateral meniscus; MRI: magnetic resonance imaging; AP: anteroposterior; EB: extension block; CDF: compensated distance to the fibular head; ICC: intraclass correlation coefficient; ANOVA: analysis of variance

Declarations

Acknowledgements

Not applicable.

Authors' contributions

YWJ contributed to the conception, design, data collection, interpretation, funding and writing of the paper. JWY contributed to the conception, design, data collection, analysis and interpretation. LC contributed data collection, interpretation and critical review. SCH and CTJ contributed to critical review. CIH contributed to data collection, interpretation, critical review as well as revision of article. All authors read and approved the final manuscript.

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Availability of data and materials

Not applicable.

Ethics approval and consent to participate

The study was approved by the institutional review board of Seoul National University Hospital No: H-1901-114-1005), which waived informed consent because of its retrospective design.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1. Intraobserver and interobserver reliabilities of measurements

Variables	Intraobserver ICC (95% CI)	Interobserver ICC (95% CI)
Fibular height on plain radiography	0.970 (0.935-0.986)	0.731 (0.489-0.868)
Femoral condylar distance on plain radiography	0.990 (0.979-0.996)	0.823 (0.648-0.916)
Fibular height on sagittal MRI	0.980 (0.955-0.991)	0.905 (0.803-0.955)
Femoral condylar distance on MRI	0.905 (0.803-0.955)	0.989 (0.977-0.995)

ICC: interclass coefficient correlation; CI: confidence interval

Table 2. Comparison of the compensated distance to the fibular head between the control and DLM groups and between the subgroups according to the presence or absence of knee EB

Imaging studies	Control group (N=82)	DLM group (N=82)		<i>p</i> -value
AP radiography	0.187 ± 0.043	0.182 ± 0.050		0.503
Sagittal MRI	0.177 ± 0.042	0.169 ± 0.048		0.250
		EB(-)	EB(+)	
		(N=39)	(N=43)	
AP radiography		0.192 ± 0.045	0.160 ± 0.052	0.006
Sagittal MRI		0.206 ± 0.049	0.193 ± 0.050	0.549
AP radiography at final follow-up		0.200 ± 0.027	0.221 ± 0.196	0.557

Values are mean ± standard deviation.

AP: anteroposterior; CDF: compensated distance to the fibular head; DLM: discoid lateral meniscus; EB: extension block

Figures

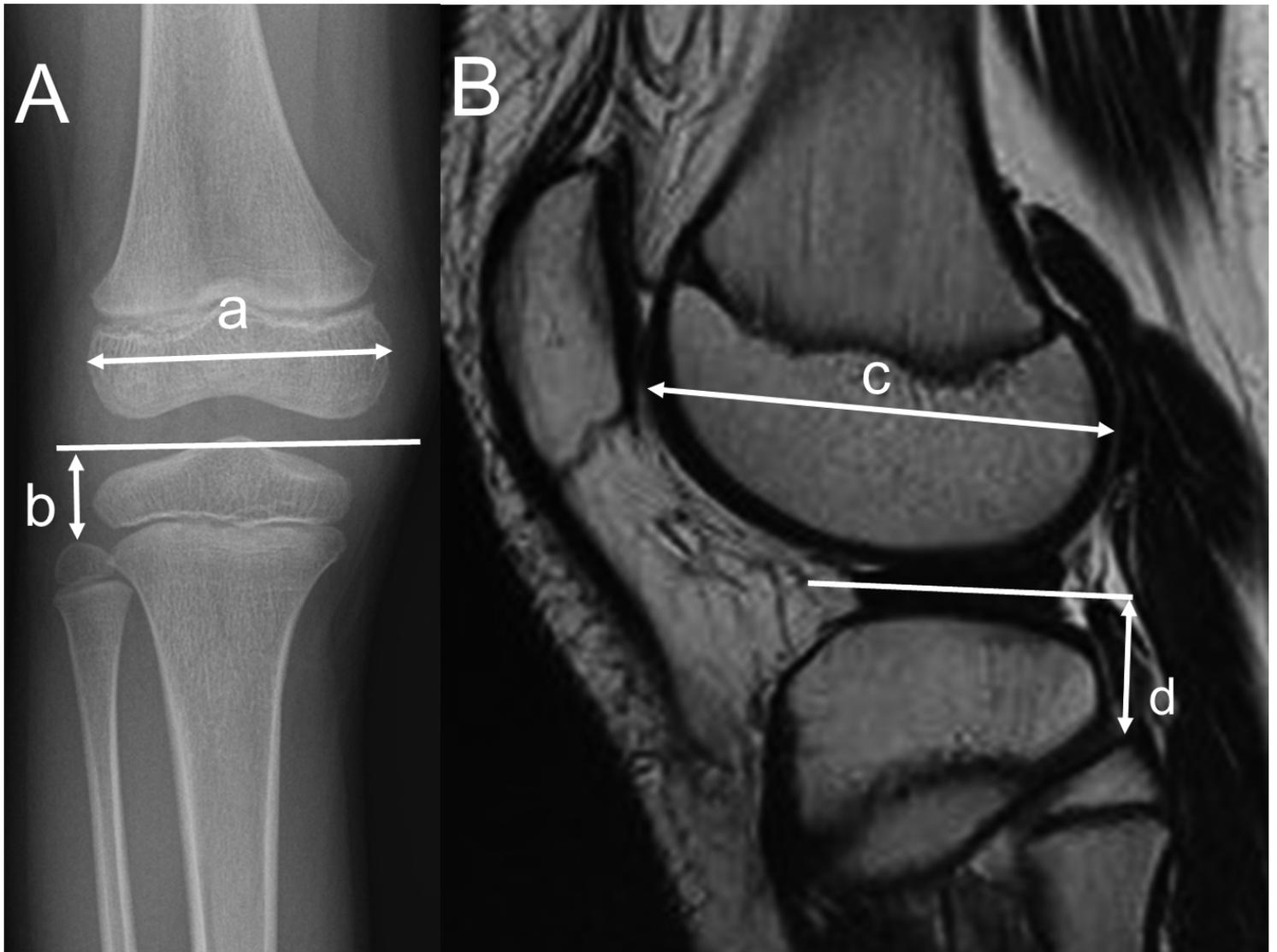


Figure 1

The CDF was calculated as a ratio of the distance from the lateral joint line to the tip of the fibular head to the femoral condylar width on plain AP radiography (A: b/a) and sagittal MR image (B: d/c). CDF: compensated distance to the fibular head; AP: anteroposterior; MR: magnetic resonance

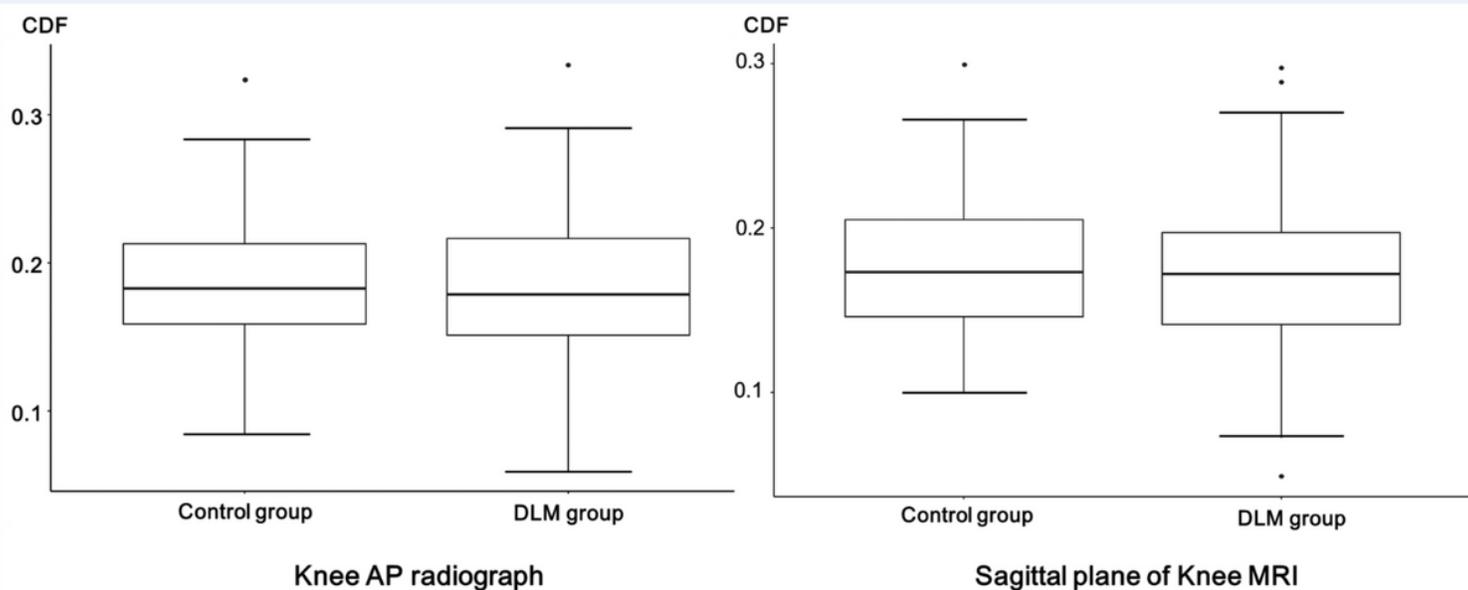


Figure 2

Comparison of the CDF between the EB(-) and EB(+) subgroups on AP plain radiography (A) and sagittal MR images (B). CDF: compensated distance to the fibular head; EB: extension block; AP: anteroposterior; MR: magnetic resonance

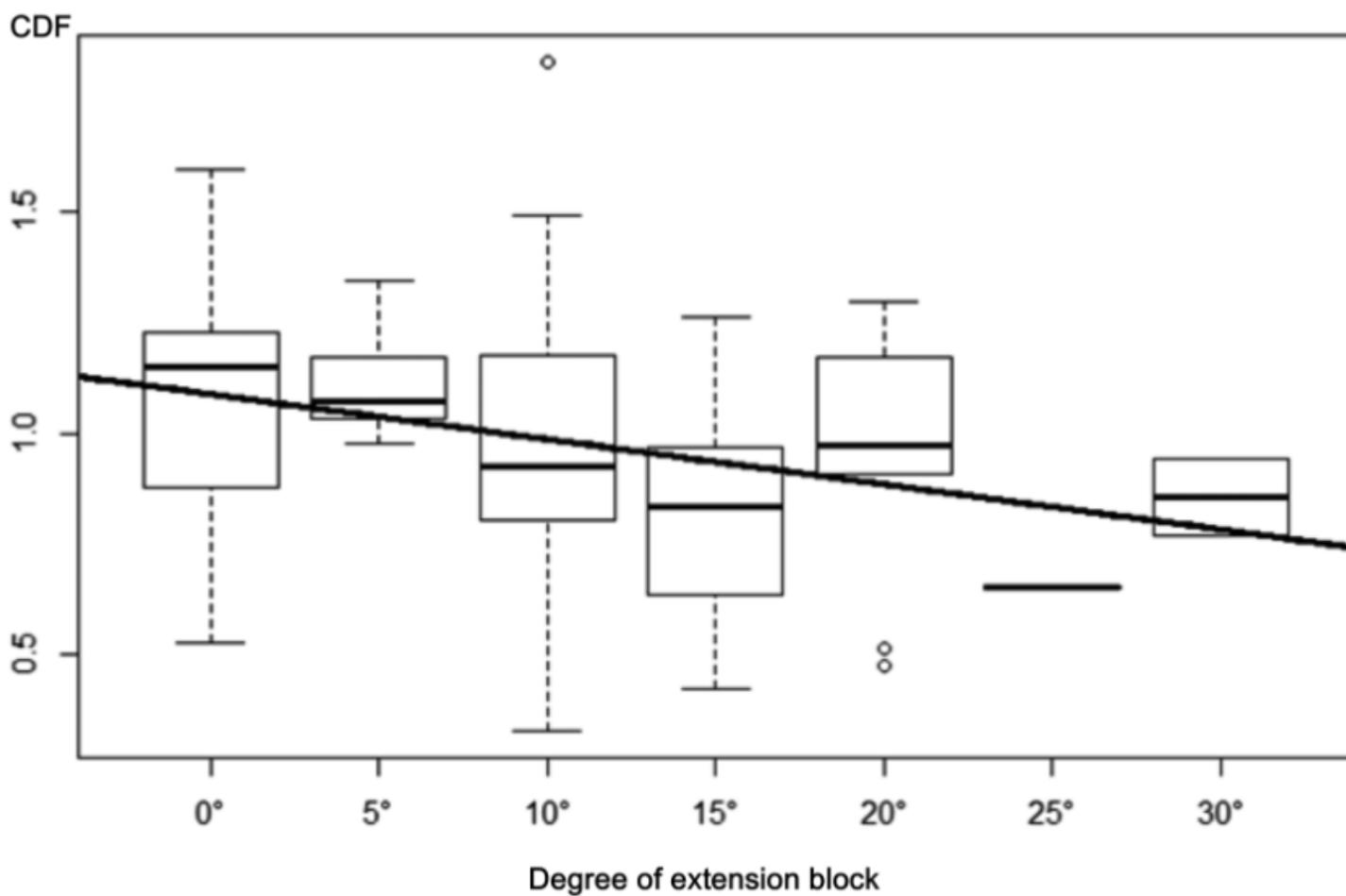


Figure 3

The CDF decreased according to the increase in knee EB ($p=0.003$). CDF: compensated distance to the fibular head; EB: extension block



Figure 4

Fibular head of the right knee appears to be located high on a preoperative AP radiograph of a six-year-old boy (A) who had a 20-degree EB on the right knee (B, C). The limited knee extension disappeared after arthroscopic partial meniscectomy and stabilization of the remnant rim, and follow-up radiography shows that the high location of the fibular head also disappeared (D). The schematic drawings illustrate a higher fibular location in the knee flexion position (E, F). AP: anteroposterior; EB: extension block

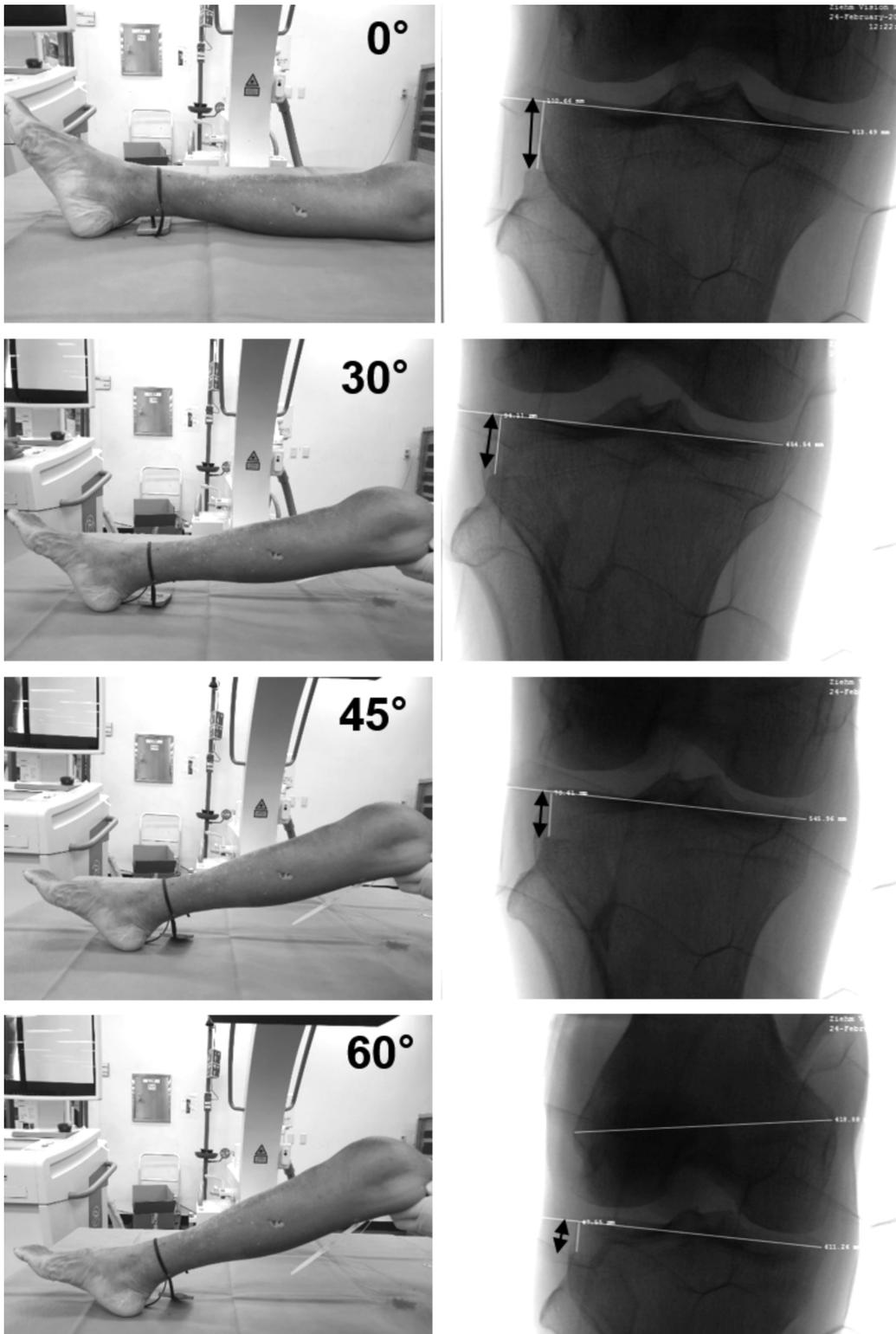


Figure 5

A cadaveric study shows that the distance between the joint line and the fibular head decreases by increasing the knee flexion angle from 0 to 60 degrees.