

CT-Based Morphological Analysis of The Distal Femur In Patients With Trochlear Dysplasia

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Research Article

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Abstract

Background: The morphology of the femoral trochlear has been well investigated; however, to date, the distal femur morphological characteristics have not been studied. The research team posited the presence of morphological differences in the distal femur in trochlear dysplasia compared to a control group. They also postulated that the underlying pathology of distal femur dysplasia is a medial hypoplasia.

Methods: Computed tomography (CT) scans of 80 knees with trochlear dysplasia and 80 knees with normal anatomy of the femoral trochlear were included. The following measurements were assessed by three observers: the distal femur angle, the percentage of medial distal femur height and the percentage of lateral distal femur height between the groups. The independent Student's t-test were used to evaluate the differences of the qualitative variables.

Results: The distal femur angle was relatively larger compared to the control group ($p < 0.001$). Percentage of the medial distal femur showed significant lower values in the study group ($p < 0.001$). No significant differences were evaluable for the percentage of lateral distal femur height ($p = 0.087$). The study group have a bigger distal femur angle and a steep medial distal femur than the control group.

Conclusion: Patients with trochlear dysplasia have a different distal femur compared with those without trochlear dysplasia. Compared to controls, patients with a dysplastic trochlea have a distal femur dysplasia, and the underlying pathology of a dysplastic distal femur is led by a medial distal femur hypoplasia.

Introduction

Morphological abnormalities of distal femur are thought to be the anatomical basis of patellofemoral disorders, especially in patients with symptomatic patellofemoral instability. Dejour et al. showed that femoral trochlear dysplasia is one of the major risk factors associated with patellofemoral instability [1]. Richmond et al. showed that the morphology of the trochlea and patella changed during skeletal development [2]. The studies by Ferlic PW et al. reported that the shear stress in the distal femur plays an important role in the development of the trochlear [3-5]. Fu et al. recently reported that early relocation of the patella can prevent the development of trochlear dysplasia in children [6]. Variation of shear stress on the distal femur theoretically might result in a morphology of the patellofemoral joint changed. The morphology of the femoral trochlea has been thoroughly studied [6-11]. However, the morphological characteristics of distal femur have not been described in patients with trochlear dysplasia. It is still unknown whether the distal femur in patients with trochlear dysplasia differs from that in those with normal. Therefore, the aim of the present study was to compare, using Computed tomography (CT), the morphology of the distal femur in patients with trochlear dysplasia with normal patients. Our study hypothesized that in patients with trochlear dysplasia, the distal femur develops hypoplasia.

Materials And Methods

The study had been approved by the Ethics Committee and all patients gave informed consent.

Consecutive CT scans of 160 knees were measured retrospectively to analyze the morphology of distal femur in patients suffering from a dysplastic trochlea and in controls. A total of 80 knees with dysplastic trochlea in the study group, 28 males and 52 females, mean age 36 years (range 18–45) were performed between 2010 and 2019. The clinical diagnosis of dysplastic trochlea in study group was confirmed by CT scans. The exclusion criterion was a history of prior surgery of the lower extremity or traumatic patellar dislocation or Multi-ligament injury or arthritis. In the control group, CT scans were performed in 80 knees, 30 males and 50 females, mean age 36 years (range 19–44), with normal morphology of the patellofemoral joint between 2010 and 2019. All controls consulted the orthopedic surgeon for a complaint, such as soft cartilage injury or avulsion fracture. Patients demographic characteristics were matched between both groups according to sex and age (Table 1).

Table 1. Demographic characteristics of the study and control groups.

	Study (n = 80)	Control (n = 80)	χ^2	P
Gender				
Male	28(35.00)	30(37.50)	0.01	0.912
Female	52 (65.00)	50 (62.50)		
Age	36.12 ± 6.52	36.48 ± 6.25	-0.16*	0.852
Side				
Right	38 (47.50)	46 (57.50)	1.82	0.176
Left	42 (52.50)	34 (42.50)		

* t-test.

CT views assessment of morphological characteristics of distal femur were performed in the supine position between the groups. Three orthopaedic surgeons assessed the following measurements: the distal femur angle, the percentage of medial distal femur height and the percentage of lateral distal femur height between the groups. All measurements were made on the axial plane. For measurements, the axial plane with the distal femur (the slice just above the point of attachment of the gastrocnemius head [12]) was chosen to measure the morphology of the distal femur. The distal femur angle was determined by a tangent to the medial facet of the distal femur. The angle between this tangent and the dorsal distal femur line (popliteal surface) was taken as the distal femur angle. The distal femur (popliteal surface) is divided into three equal sections (AE, AB and BF). The lateral distal femur height (AC) is the perpendicular distance from the lateral distal femur (A) to dorsal distal femur line (popliteal surface). The medial distal femur height (BD) is the perpendicular distance from the medial distal femur (B) to dorsal distal femur line. In the anteroposterior direction, the medial and lateral distal femur heights were measured on the distal femur axial images and expressed as a percentage of the distal femur width (EF). The methods

applied to the assessment of distal femur are summarized in Table 2 and Fig. 1–3.

Table 2. Description of measurements

distal femur morphological characteristics	
distal femur width(EF)	It is defined as the length between the medial (E) and lateral edge (F) of distal femur (Fig. 1).
distal femur angle	It is defined by two reference points, the medial slopes of distal femur and the posterior tangent line of the distal femur (Fig. 2).
medial distal femur height %	The ratio of length of medial distal femur height to distal femur width (Fig. 3).
lateral distal femur height %	The ratio of length of lateral distal femur height to distal femur width (Fig. 3).

CT scans were performed using a Sante DICOM Viewer Free (64-bit) version (Santesoft, Inc. Athens, Greece) to 0.01° for angles and 0.01 mm. For minimizing measurement error, all measurements were conducted by three blinded orthopaedic surgeons. After an interval of 3 days, the two surgeons measured the 160 samples again. The inter-and intraobserver reliabilities were then determined by calculating intra-class correlation coefficients (ICCs).

Statistical analysis SPSS statistical software (version 22.0; SPSS, IL, USA) was performed for data analyses. The data were presented as the mean and standard deviation. The normality of numerical data was assessed by the Kolmogorov–Smirnov test, the measured data passed the test. All values of the two groups were calculated with 95% confidence intervals. After establishing data normality, student's t-test were used to evaluate the differences between the two groups. The categorical values were analyzed using Chi-squared test. P-value < 0.05 was defined as the threshold for statistical significance.

Results

The demographic characteristics showed no significant differences in age, sex, and side between the two groups (Table 1). The inter-and intraobserver correlation coefficients was high between measurements (Table 3).

Table 3. Intra-observer and inter-observer agreement of geometric measurements with 95% confidence intervals.

Measurement	Intraobserver		Interobserver	
	ICC	95% CI	ICC	95% CI
Group S-DFA°	0.835	0.686 to 0.913	0.771	0.625 to 0.910
Group S-LDFD%	0.892	0.817 to 0.926	0.830	0.763 to 0.904
Group S-MDFD%	0.788	0.710 to 0.906	0.816	0.703 to 0.925
Group C-DFA°	0.889	0.820 to 0.958	0.854	0.820 to 0.929
Group C-LDFD%	0.903	0.836 to 0.931	0.865	0.738 to 0.903
Group C-MDFD%	0.815	0.738 to 0.920	0.784	0.706 to 0.905

ICC, intra-class correlation coefficient; Group S, study group; DFA° , distal femur angle; LDFD%, lateral distal femur height %; MDFD%, medial distal femur height %; Group C, control group

Many measurements showed significant differences between the two groups (Table 4). Compared with the control group, the study group had a larger distal femur angle and a smaller medial distal femur. The measurements of mean distal femur angle in the axial plane was significantly different between the groups ($P < 0.001$). In the control group, the mean distal femur angle was 11.73° . 80 knees in the study group had a femur angle of 24.92° . The percentage of medial distal femur height showed the greater difference: 56.3% in the study group versus 60.1% in the control group ($P < 0.001$). No significant differences were seen in well-known measurements such as the percentage of lateral distal femur height (the study group, 68.8%; the control group, 69.4%; $p = 0.087$). Overall, in patients with dysplastic trochlea, the distal femur morphology exhibited a steep-slope (Fig. 4).

Table 4. Results of the morphologic characteristics of the distal femur.

Indexes	Group S	Group C	p-value*
Mean DFA°	24.92 ± 7.86 (16.71-35.13)	11.73 ± 3.46 (8.42-15.76)	<0.001
Mean MDFD%	56.3 ± 7.58 (46.8-63.0)	60.1 ± 3.84 (55.7-64.1)	<0.001
Mean LDFD%	69.4 ± 3.16 (65.6-73.1)	68.8 ± 3.37 (65.3-73.1)	=0.087

*Student's t-test.

Group S, study group; Group C, control group; DFA° , distal femur angle; MDFD%, medial distal femur height %; LDFD%, lateral distal femur height %

Discussion

The key finding of the current study was that patients with dysplastic trochlea had a distal femur dysplasia and the underlying pathology of a dysplastic distal femur was led by a medial distal femur hypoplasia. It is considered that distal femur angle of more than 16 degrees as distal femur dysplasia, which could confidently differentiate between health and distal femur dysplasia. The findings have important reference value to pathogeny of patellar dislocation. In clinical surgery, it is unknown if these abnormalities influence the surgical effect after soft-tissue procedures. Physicians should pay more attention to these differences for disease diagnosis or surgical procedure.

The passive stability of the patellofemoral joint depends on the shape of the patella and femur [1]. Osteal constraint formed by the distal femur is an important restraint preventing lateral dislocation. Femoral trochlear dysplasia has long been identified as a potential risk factor for patella instability [1, 13–17]. With regard to trochlear dysplasia, the trochlea of the distal femur have continued to be published [6, 16, 18]. Andreas V et al. quantified the trochlear morphology via computed tomography and showed that the trochlear variability (a flat, shallow femur groove) in dysplasia was found in proximal third of the cartilaginous trochlea [3, 19, 20]. However, Few studies have focused on the distal femur in adults with trochlear dysplasia. The morphology of distal femur is an important factor affecting the stability of the patella [1]. Shih YF et al. found that the morphological changes in the distal femur can affect patella location [21]. So we believe that it is significative to confirm that the morphological changes of the distal femur in patients with trochlear dysplasia. As with the patellofemoral joint dysplasia, the study suggest that the distal femur also develops hypoplasia in patients with trochlea dysplasia. There are no parameters in current studies that described the contour of the distal femur, especially in trochlea dysplasia patients. Therefore, all measurements in the present study were made to evaluate the distal femur morphology. The distal femur angle and the percentage of lateral distal femur height and the percentage of medial distal femur height on a particular axial image which was the slice just above the point of attachment of the gastrocnemius head [12].

The morphological characteristics of distal femur were a main aspect of this study and yielded interesting results. In the present study, the mean distal femur angle was larger in the study group than in the control group ($P < 0.001$). In the control group, the mean distal femur angle was 11.73° . 80 knees in the study group had a groove angle of 24.92° . It is considered that distal femur angle of more than 16 degrees as distal femur dysplasia. The percentage of medial distal femur height showed a significant difference between the study group and the control group ($P < 0.001$). For percentage of lateral distal femur height, no significant differences could be found ($P = 0.087$). The study group had a steep distal femur than the control group. But how to explain this phenomenon?

We know the unique matching relation of the patella and femur, which is the basis of its biomechanical function [22]. Stress stimulation plays an important role in bone development [23]. Wolff law that illustrates that cancellous architecture is altered in response to mechanical stress [24]. In the patellofemoral joint, stress is transmitted from the subchondral bone to the cancellous bone [16]. This transmission of stress during function stimulates the growth and remodelling of the femur [25]. Without the appropriate load, the distal femur fails to fully develop. This phenomenon can also be seen in

patients suffering from hip dysplasia [26]. Associated distal femur dysplasia formation was the response to the different local stress.

There were some limitations to the study. First, single axial planes on CT scans can not be used accurately describe the morphology of distal femur. Multilayer planes are required in order of precise evaluation [27]. Second, additional parameters other than those described earlier were not able to analyze. It would have been interesting to contain more clinical data. Third, no surgical parameters were assessed. However, the purpose of this study was to assess the morphology of distal femur. Further studies could validate the changes of surgical parameters.

Conclusion

In conclusion, the present study is the first one comparing the morphology of distal femur in patients with trochlea dysplasia. The important finding was that patients with trochlea dysplasia have steep distal femur compared to health, and the underlying pathology of a dysplastic distal femur is led by a medial femur hypoplasia. It is considered that distal femur angle of more than 16 degrees as distal femur dysplasia, which could confidently differentiate between health and distal femur dysplasia. More attention should be paid to these morphological changes.

Abbreviations

CT: Computed tomography; ICC: intra-class correlation coefficient; Group S: study group; DFA° : distal femur angle; LDFD%: lateral distal femur height %; MDFD%: medial distal femur height %; Group C: control group.

Declarations

Acknowledgments

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Authors' contributions

WFL, and SYW designed the study. HL collected the samples and processed the statistical analysis. QW draw the manuscript and made the figures and tables. All authors participated in the writing of the manuscript and agreed to the publication.

Role of the funding source

The funding sources were not involved in the design, collection, analysis, and interpretation of the data, or in the writing of the

manuscript.

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Availability of data and materials

The detailed data and materials of this study were available from the corresponding author through emails on reasonable request.

Ethics declarations

This study was approved by 1st Central Hospital of Baoding

Research Ethics Committee ([2019]-N21). All subjects provided informed consent to take part in the study. All procedures were conducted according to the 1964 Declaration of Helsinki and its amendments.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Figures

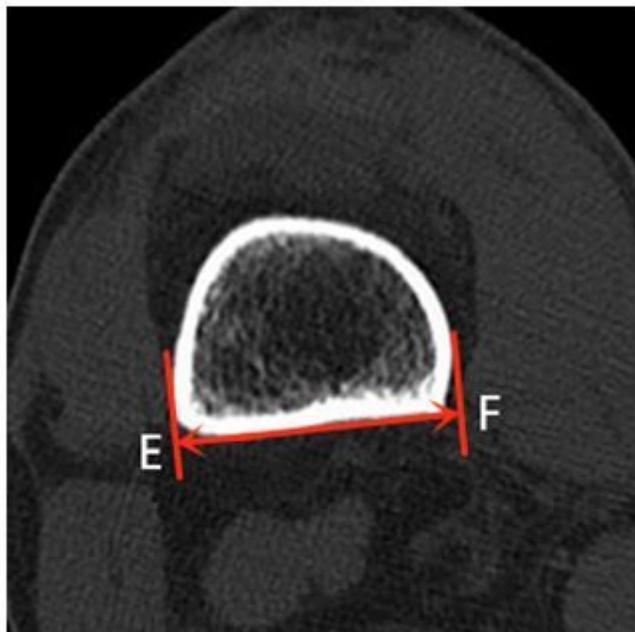


Figure 1

The distal femur width(EF) is the length between the medial (E) and lateral edge (F) of distal femur.

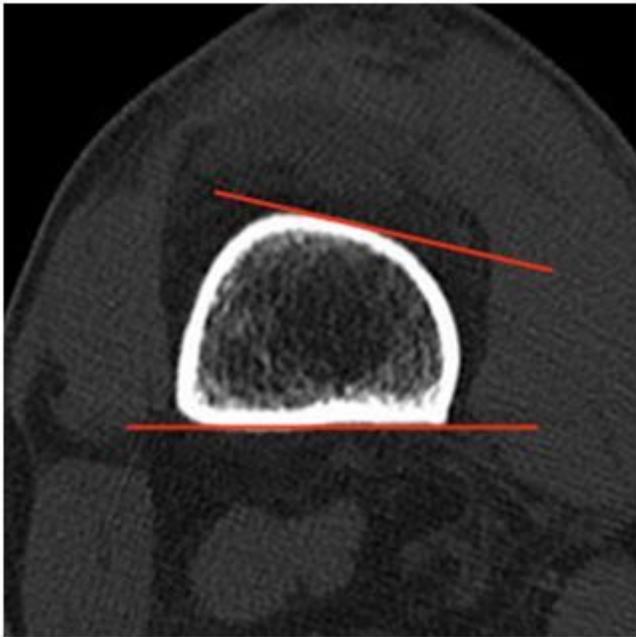


Figure 2

The distal femur angle between the medial facet of the distal femur tangent and the dorsal distal femur line (popliteal surface).

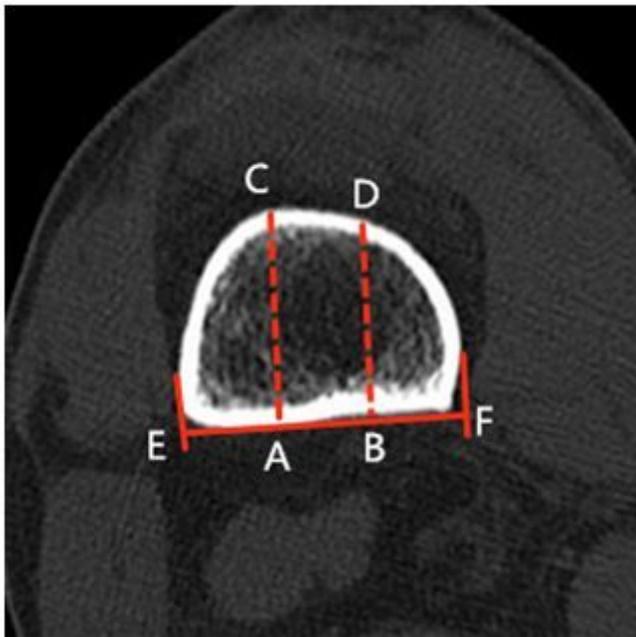


Figure 3

Measurement of lateral (AC), and medial (BD) distal femur height on an axial computed tomography slice. EF indicates the total width of distal femur (i.e., 100%).

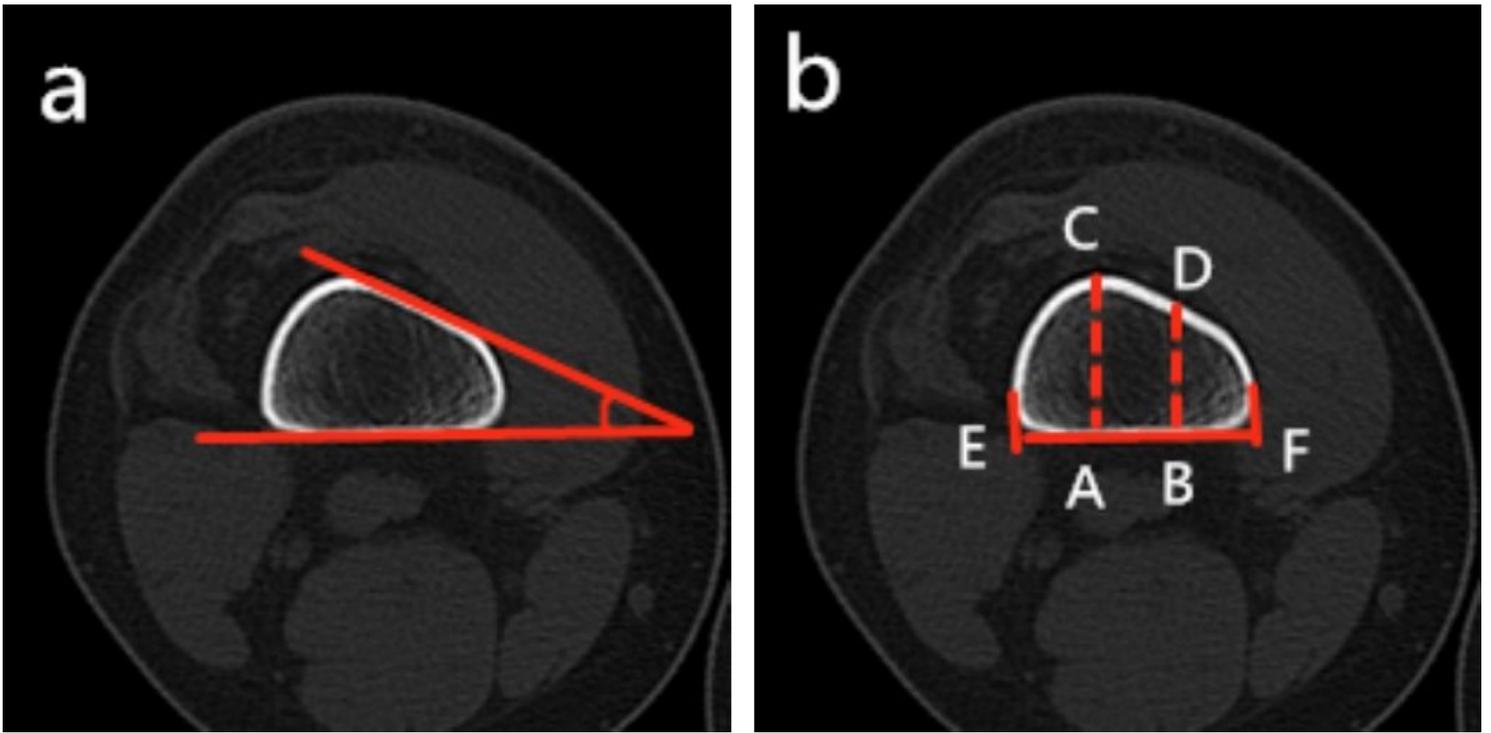


Figure 4

Distal femur dysplasia according of left knee (a the distal femur angle, b the lateral height of distal femur (AC) and the medial height of distal femur (BD))