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Evaluation of Trochlear Dysplasia Severity Using Trochlear Angle: A Retrospective Study Based on Computed Tomography (CT) Scans

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Background: Trochlear dysplasia is an important pathological factor in patellofemoral instability. Quantitative evaluation of the severity of trochlear dysplasia is rare and remains unclear.

Material/Methods: Computed tomography (CT) data on 136 knees (95 patients) with trochlear dysplasia in the case group and an age- and sex-matched cohort of 120 knees (70 patients) in the control group were collected for this retrospective study. All participants had undergone CT scans in the supine position. The trochlear angles (TA) formed by the posterior condylar line and the trochlear line were calculated and compared. The threshold for statistical significance was set at $p<0.05$.

Results: The mean TA values were significantly greater in the case group compared to the control group independent of sex ($p<0.01$). The distribution of trochlear dysplasia of Dejour grades was type A n=34, type B n=31, type C n=40, and type D n=31. Except for types A and B, differences in the trochlear dysplasia grade between any 2 other types were statistically significant ($p<0.01$).

Conclusions: The technique of measuring TA is reproducible and accurate in patients with patellar instability and normal controls. The TA positively correlates with higher levels of trochlear dysplasia. This technique can help to evaluate and treat trochlear dysplasia in research as well as in clinical practice.

MeSH Keywords: **Evaluation Studies as Topic • Patellar Dislocation • Tomography, Spiral Computed**

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Background

Patellofemoral instability is common in adolescents and children. The incidence of primary patellar dislocation is approximately 6 per 100 000, peaking at a rate of 21 per 100 000 in 10–17-year-olds [1]

Since the femoral trochlea plays the most significant role with flexion > 30°, where the soft-tissue constraint becomes minimized in patellofemoral stability, the morphology of the femoral trochlea drastically influences patellofemoral stability as the knee continues to flex [2]. Trochlear dysplasia, characterized as an abnormality of the shape and depth of the trochlear groove, has been generally recognized as a significant predisposing factor for patellofemoral instability for many years. Due to considerable individual variability in regard to the morphology of dysplastic trochlea, the diagnosis, classification, and treatment of trochlear dysplasia is still difficult. Dejour and Le Coultre classified trochlear dysplasia into 4 types (A, B, C, and D) in terms of the crossing sign or the sulcus angle >or <145°, the supratrochlear "bump" or "spur," the double contour, and the cliff sign, respectively on lateral radiography and computed tomography (CT) scans [3].This classification is currently the most popular, and is usually considered to be the criterion standard in clinical practice and orthopedic research. However, the inter- and intra-observer reproducibility of this classification remains controversial, probably because identifying these typical signs depends on subjective visual appraisal [4,5]. To reduce the influence of observer experience and subjectivity, various other quantitative parameters have been described to assess the femoral trochlea [6–9]. Pfirrmann et al. reported using trochlear depth and facet asymmetry, condyle asymmetry, and lateralization of the patella to evaluate the morphology of the femoral trochlea. Their findings showed that trochlear depth and facet asymmetry, with the cut-off values of 3 cm and 2: 5, respectively, both had a sensitivity of 100% and a specificity of 96% on axial magnetic resonance imaging (MRI) scans 3 cm above the femorotibial joint space [9]. Carrillon et al. described the lateral trochlear inclination, measured on the first image to display cartilaginous trochlea, to estimate trochlear dysplasia. A cut-off value of 11° was determined with a sensitivity of 93% and a specificity of 87% and was reliable to discriminate between normal and dysplastic trochlea [6]. Biedert and Bachmann calculated the lateral condylar height, the central condylar height, and the medial condylar height to build a database of normal and abnormal trochlear morphology and to classify trochlear dysplasia. The results of their study showed that in most cases with trochlear dysplasia, central and/or medial heights decreased significantly more than in normal cases. Measurements were made on the first section containing cartilage along the entire width of the trochlea beginning proximally [8]. Most of these parameters had good performance on separating normal and dysplastic trochlea. However, none of these quantitative parameters were used to develop different grades of severity of trochlear dysplasia when they were put forward in the literature. Nelitz et al. attempted to differentiate different types of trochlear dysplasia using condylar height, trochlear depth, and facet asymmetry. Unfortunately, even though these parameters allowed them to distinguish between low-grade and high-grade dysplasia, with substantial sensitivity and specificity, the results were less robust than expected [10]. None of these parameters could be assigned to the 4-grade classification of trochlear dysplasia of Dejour and, in high-grade types, measurements could not be reliably performed because several anatomical landmarks were impractical to identify in the presence of severe trochlear dysplasia. Hence, there remains a question of whether a quantitative parameter can objectively evaluate the severity of trochlear dysplasia.

Here, we hypothesized that measuring the trochlear angle (TA) can quantify the severity of trochlear dysplasia and provide objective information for diagnosis and treatment of trochlear dysplasia. We aimed to objectively evaluate the severity of trochlear dysplasia using the TA.

Material and Methods

Participants

The present study was approved by our Institutional Review Board, and informed consent was obtained from all participants. From January 2014 to June 2017, we retrospectively analyzed CT images of knee joints in 2 groups of patients. The first group included 136 knees (61 males, 75 females) in 85 patients (mean age 21.3±3.1 years) with patellar instability. Inclusion criteria were: (1) more than 2 episodes of dislocation or 1 episode of dislocation plus multiple episodes of instability, or a history of patellar dislocation and patellar instability symptoms (pain, subluxation, or both) for >3 months after the first dislocation; and (2) a positive patellar apprehension sign and excessive external patellar divergence on CT. Exclusion criteria were prior surgery of the lower extremity, acute patellar dislocation, and evident patellofemoral arthritis. The control group included 120 knees (53 males, 67 females) in 75 patients (mean age 21.0±2.2 years) who had other knee problems, such as a slight soft tissue injury or avulsion fracture and were consecutively selected from ordinary referrals for knee CT examinations during the same period. The control group was matched with the patellar instability group according to sex and age. The diagnosis and classification of trochlear dysplasia were confirmed based on axial CT images by 2 authors according to Dejour classification. Intra-class correlation coefficient values (ICC) were calculated to test their intra- and inter-observer reliability.

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CT protocols and measurements

All participants underwent CT scans in the supine position, with the knee fully extended with neutral or slight external rotation as needed for comfort. Straps were wrapped around the thigh and lower leg to minimize motion. A 16-detector row CT scanner (SOMATOM Sensation 16; Siemens Medical Solutions, Erlangen, Germany) was used. These CT scans were acquired using the following parameters: 512×512 matrix, 120 kV, 100 mAs, 1 s rotation time, 1 mm slice thickness, 0 mm slice skip, a 14 cm field of view, and bone kernel. The CT images obtained were then imported into a personal computer to carry out our measurements using RadiAnt DICOM software (Medical Ltd., Poznan, Poland) with an accuracy of 0.1 degrees for CT image analysis.

The trochlear angle was defined as the angle between the posterior condylar line (PCL) and the trochlear line (TL) [11–13] (Figure 1). The PCL was drawn along the most posterior margin of the medial and lateral trochlear facets, and the TL was a line passing along the most anterior margin of the medial and lateral trochlear facets. Measurements were performed on the axial CT slice with the most prominent posterior condyle [11]. Two authors, blinded to the characteristics of the patients, independently established all measurements. Twenty randomly selected patients' CT images were measured twice with a 2-week interval between measurements.

Statistical analysis

All analyses were conducted using the IBM SPSS Statistics version 22.0 software package (IBM Inc., Chicago, IL, USA). The Kolmogorov-Smirnov normality test was performed to test whether our data fit a Gaussian distribution and all data passed the test. The intra-observer and inter-observer reliability were determined by calculating the ICC which were thought to be slight for an ICC <0.21, fair if it was 0.21–0.40, moderate if it was 0.41–0.60, substantial if it was 0.61–0.80, and almost perfect if it was >0.80.

The means of case and control groups were compared using the 2 independent-samples *t* test. The receiver operating characteristic curve (ROC) was drawn using MedCalc statistical software (Mariekerke, Belgium) [14]. Then, the area under the curve (AUC) and its 95%CI were calculated. The cut-off value was selected by determining the value that provided the highest accuracy (minimal false-negative and false-positive findings), and its specificity, sensitivity, and Youden index (specificity+sensitivity–1) were also calculated. The one-way ANOVA test and LSD (least significant difference) *t* test (if needed) was performed to compare the means of the 4 types of trochlear dysplasia. The χ^2 test was used to test for categorical values. The threshold for statistical significance was set at $p<0.05$.

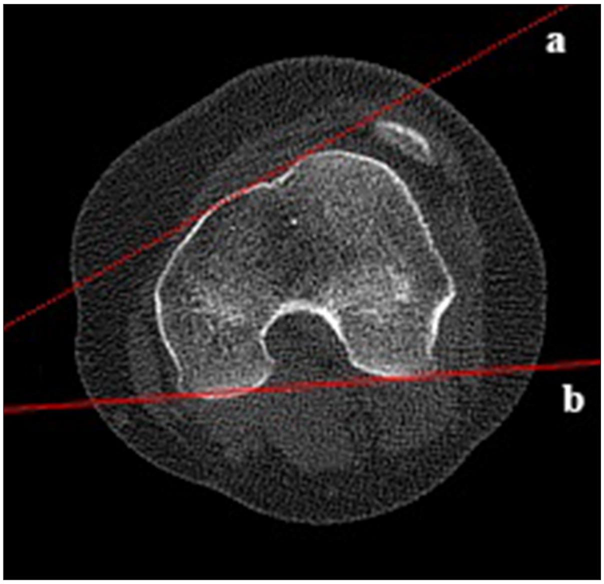

Figure 1. Line a: Trochlear line. Line b: Posterior condylar line.

Based on an estimated sensitivity of 0.80 with a confidence level of 95% (α=0.05) and a power (1–β) of 80%, a sample size of 120 knees per group was required.

Results

All data are expressed as mean ± standard deviation. There were no significant differences in BMI between the case (22.9±2.5) and control (21.3±2.7) groups. The intra-observer and the inter-observer intra-class correlation coefficient were almost perfect for the TA measurements, which indicated that it is highly reproducible (intra-observer ICC=0.987, 95%CI 0.985–0.990; inter-observer ICC=0.991, 95%CI 0.989–0.993).

The mean TA values of case and control groups were 13.6±5.7° and 5.6±3.1°, respectively (p<0.01). There was no significant difference in TA between males and females in case and control groups (female 9.5±6.2°, male 10.1±6.1°). The AUC was 0.88 (a chance that a case has a higher value than control), which indicates excellent accuracy. Based on the cut-off values of 8°, specificity, sensitivity, and Youden index of TA were 0.79, 0.81, and 0.60, respectively.

The scoring of trochlear dysplasia resulted in the following distribution: type A n=34, type B n=31, type C n=40, and type D n=31(ICC=0.91, 0.89). The mean values of type A, B, C, and D were 8.9±4.4°, 10.5±4.6°, 15.7±3.3°, and 19.2±4.1°, respectively. The distributions of each type are shown in Figure 2. The one-way ANOVA test resulted in F=38.5, p<0.01; further analysis with the LSD *t* test revealed no significant difference between types A and B, and significant differences in the TA between any other 2 types (p<0.01).

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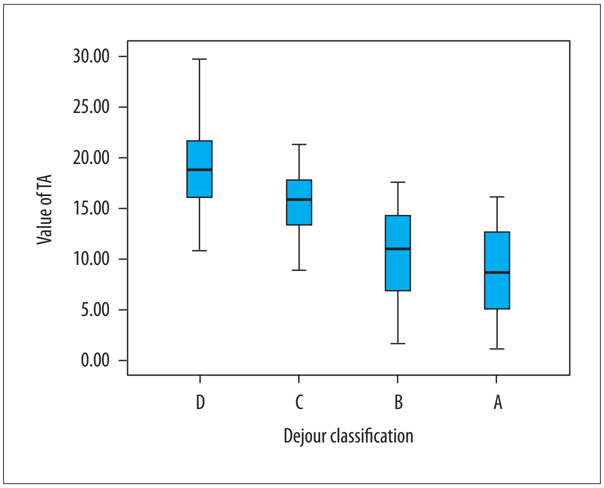

Figure 2. Distribution of TA values of different types of trochlear dysplasia.

Discussion

The important finding of this study is that the TA can be used to quantitatively evaluate the severity of severe trochlear dysplasia, since in cases of severe trochlear dysplasia, this parameter tends to increase progressively and significantly along with the severity of trochlear dysplasia, with excellent inter-observer and intra-observer agreement. In addition, the cut-off value of TA was 8°, which could confidently differentiate between normal and dysplastic trochlea with the sensitivity of 0.81 and the specificity of 0.79. Importantly, there was no significant difference in TA values between types A and B, which might limit the usefulness of TA in differentiating between low- and high-grade trochlear dysplasia. Hence, TA may be best suited for quantitative analysis of severe trochlear dysplasia.

TA has been used to assess trochlear morphology in patellofemoral osteoarthritis in previous studies [11–13], but none of these studies used TA to evaluate trochlear dysplasia without comparison with the types of Dejour classification. The measurement of TA can be reliably performed on all patients because the 2 tangential lines to the anterior and posterior condyles are easy to define. We chose the CT slice with the most prominent posterior condylar line to perform all measurements rather than the section 3 cm above the joint space or the most proximal slice containing the entire width of the trochlea, since the values of TA may be affected by variations in the size of the distal femur, and because the most proximal slice that contains the entire width of the femoral trochlea is often too far proximal to show the posterior condyle. We did not set cut-off values of the TA in different types of trochlear dysplasia because the size of each subgroup was small. Furthermore, Lippacher et al. found that Dejour classification was only valid for separating low-grade from high-grade dysplasia and had low validity for differentiating types of high-grade trochlear dysplasia [5].

The salient finding of the present study is that the mean TA showed a significant positive correlation with Dejour type from B to D. Many studies have recommended that severe trochlear dysplasia should be corrected by a tracheloplasty procedure for long-term patellar stability [15–19]. Several investigators have deemed severe trochlear dysplasia to be a significant negative prognostic risk factor for other procedures performed without managing trochlear dysplasia [20]. With the advancement of surgical techniques and instruments, the trochleoplasty, aiming to restore the normal anatomy of trochlea and patellar stability, is increasingly popular. However, this procedure is still a relatively rare choice for orthopedic surgeons due to the complicated morphology of severe trochlear dysplasia. Surgical failures and postoperative complications still confront orthopedic surgeons with a dilemma. Hence, to achieve a successful operation and avoid postoperative complications, the evaluation of severe trochlear dysplasia needs to be more objective and accurate.

One limitation of our study is that we chose CT rather than MR, which is free from radiation exposure. Compared to MR, CT has a higher resolution and linearity of osteological features and cartilage. Since low-dose helical CT scans are in common use, this study should not be restricted by radiation. Another shortcoming is the fact that use of transverse sections only cannot reflect all the morphological characteristics of the dysplastic trochlea. Hence, sagittal sections should also be considered in assessment, as well as professional physical examination.

Conclusions

We found that the technique of measuring TA is reproducible and accurate in differentiating patients with patellar instability from normal controls and that the quantitative value of TA positively correlates with higher levels of trochlear dysplasia. This technique may help to evaluate and treat trochlear dysplasia in research and in clinical practice.

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Conflict of interest

None.

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