Anatomical Knee Variants in Discoid Lateral Meniscal Tears

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Abstract

Background: Discoid lateral meniscus was a common meniscal dysplasia and was predisposed to tear. There were some anatomical knee variants in patients with discoid lateral meniscus. The aim of this study was to analyze the relationship between anatomical knee variants and discoid lateral meniscal tears.

Methods: There were totally 125 cases of discoid lateral meniscus enrolled in this study from February 2008 to December 2013. Eighty-seven patients who underwent arthroscopic surgery for right torn discoid lateral meniscus were enrolled in the torn group. An additional 38 patients who were incidentally identified as having intact discoid lateral menisci on magnetic resonance imaging (MRI) findings were included in the control group. All patients were evaluated for anatomical knee variants on plain radiographs, including lateral joint space distance, height of the lateral tibial spine, height of the fibular head, obliquity of the lateral tibial plateau, squaring of the lateral femoral condyle, cupping of the lateral tibial plateau, lateral femoral condylar notch, and condylar cutoff sign. The relationship between anatomical variants and meniscal tear was evaluated. These anatomical variants in cases with complete discoid meniscus were also compared with those in cases with incomplete discoid meniscus.

Results: There were no significant differences between the two groups in lateral joint space distance ($P = 0.528$), height of the lateral tibial spine ($P = 0.927$), height of the fibular head ($P = 0.684$), obliquity of the lateral tibial plateau ($P = 0.672$), and the positive rates of squaring of the lateral femoral condyle ($P = 0.665$), cupping of the lateral tibial plateau ($P = 0.239$), and lateral femoral condylar notch ($P = 0.624$). The condylar cutoff sign was significantly different between the two groups, with the prominence ratio in the torn group being smaller than that in the control group (0.74 ± 0.11 vs. 0.81 ± 0.04, $P = 0.049$). With the decision value of the prominence ratio (0.78) in predicting discoid lateral meniscal tear, the sensitivity and specificity of the cutoff sign were 66% and 71%, respectively. There were no significant differences in radiographic variants between the complete and incomplete discoid lateral meniscal groups.

Conclusions: The condylar cutoff sign observed on the tunnel view of the radiograph is helpful in predicting meniscal tear in adult patients with discoid lateral meniscus. As for these patients, further MRI test is recommended.

Key words: Anatomy; Knee Joint; Lateral Menisci; Radiography

Introduction

Discoid meniscus, one of the most common anatomic variations of the meniscus, was first described in cadavers by Young in 1889.[1] Discoid lateral meniscus is more common, with a prevalence ranging from 0.4% to 17.0%,[2] compared to 0.06–0.30% for medial menisci.[3] It was reported that the incidence of tear or degeneration of discoid menisci was twice as high as normal menisci.[4,5] However, there is still no sufficient evidence explaining the predisposition to tear of discoid menisci.

Discoid lateral meniscus is thicker and discoid shaped and covers greater area of the tibial plateau than normal menisci.[6] Recent studies have indicated that the discoid lateral meniscus also represented an inner structural lesion.[7,8] The number and heterogeneous course of collagen fibers is decreased, and the discontinuity and inhomogeneity of the circumferential collagen network are increased.[7] In addition,

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there are also some other anatomical knee variants that are associated with discoid meniscus, including hypoplasia or dysplasia of femoral condyle,[9,10] fibular head, lateral tibial spine[11] and plateau.[12] On plain radiography, these variants are visualized as a widened joint space, higher fibular head, squared lateral femoral condyle, hypoplasia of the lateral tibial spine, lateral femoral condylar notch, cutoff sign of the lateral femoral condyle, and cupping and obliquity of the lateral tibial plateau.[6,10-13]

All the above observations partially account for the higher frequency of meniscal tears and associated symptoms of the discoid lateral meniscus. Despite these findings, not all discoid lateral menisci will rupture or present symptoms. There are many etiological and pathophysiological factors related to meniscal tears, such as sex, sports, sides of limbs, and degeneration.[14-16] Previous studies have indicated that age also plays a major role.[15,16] The thickness of the discoid lateral meniscus was reported to relate to meniscal tears.[17] In torn complete discoid lateral meniscus, height of the posterior horn of the lateral meniscus and the ratio of height of the lateral to the medial meniscus were both significantly larger.[17] However, there is less information regarding whether tears of the discoid lateral menisci are predisposed by anatomical knee variants. We hypothesize that there are significant differences in some anatomical features of the knee between meniscal tear and notear patients with discoid lateral menisci. In this study, to better understand the association between the anatomic knee variance in discoid lateral menisci and meniscal tears, we quantitatively analyzed and compared knee variants in plain radiographs between patients with torn discoid lateral menisci and matched untorn controls.

Methods

Study design

We retrospectively investigated 184 patients with discoid lateral meniscus between February 2008 and December 2013. There were 146 patients (with 170 knees) who underwent arthroscopic surgery for a torn discoid lateral meniscus. The diagnosis of a discoid lateral meniscus was obtained based on both the magnetic resonance imaging (MRI) and arthroscopic findings. To avoid measuring the deviation of skeletally immature or degenerative knees with osteoarthritis, patients with clear trauma history, combined with other knee injuries, and a Wrisberg type discoid lateral meniscus were excluded from the study. To eliminate the effect of limb sides, the uniform sides of the limb, only patients with discoid lateral meniscus of the right knee were included in the study. Finally, there were 87 patients with right torn discoid lateral meniscus enrolled in the torn group, consisting of complete discoid meniscus in 49 cases and incomplete discoid meniscus in 38 cases. Thirty-eight patients (complete 20 cases and incomplete 18 cases) whose right knees were incidentally identified as intact discoid lateral menisci on MRI findings were selected for the control group. Most patients in the control group accepted the MRI test for knee pain or swelling for unknown reasons. Fewer patients accepted it for a health examination. This study protocol was approved by Institutional Review Board of Hong-Hui Hospital.

Radiographic anatomical variant analysis

All patients had plain radiographs, each including the weightbearing anteroposterior and lateral view and non-weightbearing tunnel views. Each plain radiograph was performed using the same tube-to-film distance of 110 cm. The tunnel view was obtained when the patient was prone with the knee flexed approximately 40° with the foot supported by foam blocks. On each plain radiograph of the anteroposterior view, we evaluated the following variables: lateral joint space distance, height of the fibular head, height of the lateral tibial spine, squaring of the lateral femoral condyle, and cupping and obliquity of the lateral tibial plateau [Figure 1]. The lateral femoral condylar notch was measured on the lateral view [Figure 1]. The measuring methods were based on the report of Choi *et al*.[6] The condylar cutoff sign was evaluated on tunnel view radiographs using the method reported by Ha *et al*.[10] In addition, the condylar prominence ratio of the lateral and medial femoral condyles adjacent to the intercondylar notch was used to define and quantify the condylar cutoff sign [Figure 1]. The decision values of the lateral joint space, height of the lateral tibial spine, height of the fibular head, and obliquity of the lateral femoral condyle were ruled as 6 mm, 7 mm, 14 mm, and 17.5°, respectively. As for the condylar prominence ratio of the cutoff sign, we chose ten different cutoff points (0.70, 0.72, 0.74, 0.76, 0.78, 0.80, 0.82, 0.84, 0.86, and 0.88) and analyzed each by Chi-square test. The sensitivity and specificity values were analyzed according to different cutoff points. Finally, 0.78 point showed the best sensitivity and specificity. Two experienced musculoskeletal radiologists, who were blind to the arthroscopic findings, clinical history, and initial radiographic interpretations, retrospectively reviewed all the radiographs for both groups. Data including age, sex, and body mass index (BMI) were also collected.

Statistical analysis

All analyses were performed using SPSS version 15.0 (SPSS Inc., Chicago, IL, USA). The data were expressed as mean ± standard deviation (SD), median (range), or as a percentage of subjects. Differences in the values of variables among groups were assessed using analysis of variance and unpaired *t*-test. Chi-square test or Fisher's exact test was applied for dichotomous variables. A value of $P < 0.05$ was considered statistically significant. The intraclass correlation coefficient was used to evaluate the inter- and intra-observer reliability.[6]

Results

Table 1 shows demographic characteristics of the two groups. There were no significant differences in age, sex, BMI, and discoid meniscal types between the two groups. One hundred and twenty (96.0%) of the 125 knees showed more than one characteristic radiological finding of discoid

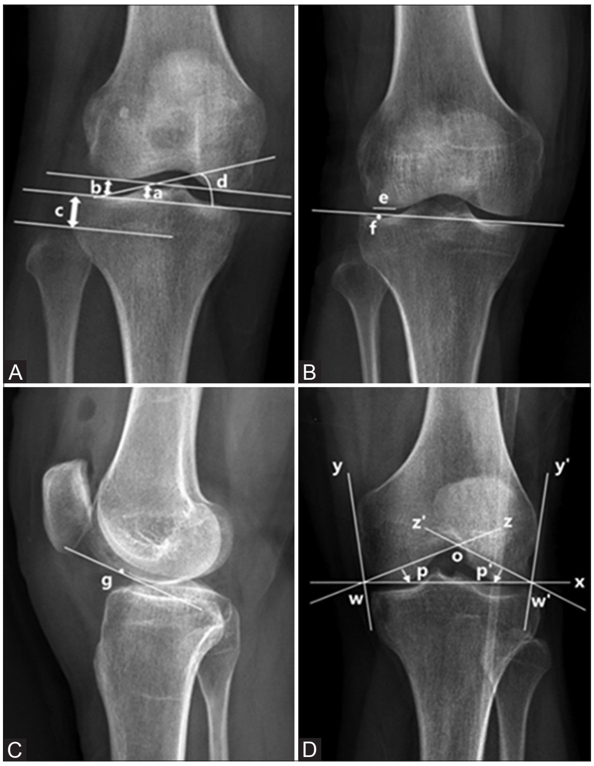

Figure 1: Diagrams of measurements of anatomical variables. (A and B) An anteroposterior view radiograph of the right knee; (C) a lateral view radiograph of the right knee; (D) a tunnel view radiograph of the right knee. a: Height of lateral tibial spine, distance from the imaginary tibial joint line to tip of the lateral tibial spine. b: Lateral joint space, from the imaginary tibial joint line to lateral condylar joint line at its midportion. c: Height of fibular head, from the imaginary tibial joint line to tip of fibular head. d: Obliquity of lateral tibial plateau angle formed by imaginary tibial joint line and articular line of the lateral tibial plateau. e: Squaring of the lateral femoral condyle, distance of straight articular surface of condyle. f: Cupping of the lateral tibial plateau, from the imaginary tibial joint line to proximal limit of the lateral tibial plateau, positive if measured above 1 mm. g: Lateral femoral condylar notch, from the tangential line, which meets smooth contour of articular surface to notch, positive if above 1 mm (a-g: reported by Choi *et al.*[6]). (D) The measurement to produce the condylar prominence ratio as a way to define and quantify the cutoff sign. Lines y and y' are drawn through the outermost points of the femoral condyle medially and laterally. Line x is drawn through the lowest points of the femoral condyles. Points w and w' are the intersections of lines y and y' and line x. Point o is the highest point in the intercondylar notch. Lines z and z' are the lines through points o and w (w'). The prominences p and p' are measured as the longest distance between the prominences of the condyles and lines z and z'. The prominence ratio is defined as p'/p (the measurement of prominence ratio reported by Ha *et al*.[10]).

lateral menisci. Furthermore, 93 (74.4%) knees had more than two characteristic findings.

Radiographic dimensions of the torn and control groups are listed in Table 2. Only the condylar cutoff sign of the two groups showed a statistically significant difference. The prominence ratio of the lateral and medial femoral condyles in the torn group was significantly smaller than that in the control group (0.74 ± 0.11 vs. 0.81 ± 0.04, P = 0.049), suggesting that the lateral femoral condyles of the torn group were less round and more sharp. With a decision value of 0.78, the condylar cutoff sign for the prediction of a discoid lateral meniscus tear revealed 66% sensitivity, 71% specificity, 84% positive predictive value, and 47% negative predictive value. There were no significant differences between the two groups in lateral joint space distance (P = 0.528), height of the lateral tibial spine (P = 0.927), height of the fibular head (P = 0.684), obliquity of the lateral tibial plateau (P = 0.672), and the positive rates of squaring of the lateral femoral condyle (P = 0.665), cupping of the lateral tibial plateau (P = 0.239) and lateral femoral condylar notch (P = 0.624). The inter- and intra-observer reliabilities for each of the variants are shown in Table 3. There was a significantly high consistency between both of the evaluators and between both of the groups.

Radiographic dimensions of all patients were also compared according to different types of discoid lateral meniscus in Table 4. The lateral joint space of the complete discoid lateral meniscus (7.06 ± 1.92 mm) appeared larger than that of the incomplete discoid lateral meniscus (6.76 ± 2.03 mm), although this difference was not significant (P = 0.092). The other radiographic variants did not have any significant differences between complete and incomplete discoid lateral menisci.

Discussion

The most important finding of the present study was that there was a significant difference in the condylar prominence ratio between the two groups, indicating a relationship between the condylar cutoff sign and discoid lateral meniscal tear. When the condylar prominence ratio was <0.78, the risk of tear for discoid lateral menisci would increase.

Characteristic findings of discoid lateral meniscus on plain radiographs are often subtle. However, these small anatomical knee variants are still sufficiently interesting to attract the attention of many scholars. Historically, most examiners thought that plain radiographs were not helpful in the detection and diagnosis of a discoid lateral meniscus.[11,18] However, with increasing characteristic anatomical variants discovered on plain radiographs,[10-13] more scholars have realized the value of these variants. Bellier *et al*.[19] found that 36.8% of children with a discoid lateral meniscus had characteristic anatomical variants on plain radiographs, such as a wider lateral joint space, greater obliquity of the lateral tibial plateau, and stunted lateral tibial eminence. In the study of Ahn *et al*.,[20] they analyzed the contralateral knee meniscus status of 33 patients who underwent an operation for a symptomatic discoid lateral meniscus and reported that 70% of contralateral knees had more than one characteristic radiographic findings of a discoid lateral meniscus. In addition, there was significant and good consistency between the radiographic findings, tear pattern of the lateral menisci, and associated chondral lesions identified on the MRI scans. Kim *et al*.[13] retrospectively reviewed and analyzed the characteristic features of 68 discoid lateral meniscus and seventy normal knees in adults with various

Table 1: Demographic characteristics of the patients in this study

Characteristics	Torn group (n = 87)	Control group (n = 38)	Statistical values	P
Age (years)	34.3 (7–68)	31.8 (9–61)	0.884*	0.377
Gender			0.550†	0.458
Male	35 (40.2)	18 (47.4)		
Female	52 (59.8)	20 (52.6)		
BMI (kg/m²)	23.2 (15.1–32.7)	22.7 (15.0–30.4)	1.591*	0.114
Meniscal sort			0.145†	0.703
Complete	49 (56.3)	20 (42.6)		
Incomplete	38 (43.7)	18 (47.4)		

Values are presented as median (range) or n (%). *t value; †χ^2 value. BMI: Body mass index.

Table 2: Radiographic dimensions of torn and control groups

Variables	Torn group (n = 87)	Control group (n = 38)	Statistical values	P
Lateral joint space (mm)	6.94 ± 2.00	7.18 ± 1.87	0.633*	0.528
Height of lateral tibial spine (mm)	6.74 ± 1.36	6.71 ± 1.49	0.092*	0.927
Height of the fibular head (mm)	12.54 ± 2.75	12.32 ± 2.99	0.408*	0.684
Obliquity of the lateral tibial plateau (°)	16.54 ± 1.66	16.39 ± 1.99	0.423*	0.672
Squaring of the lateral femoral condyle (%)	34 (39.1)	16 (43.2)	0.188†	0.665
Cupping of the lateral tibial plateau (%)	28 (32.2)	16 (43.2)	1.383†	0.239
Lateral femoral condylar notch (%)	5 (5.8)	3 (8.1)	0.240†	0.624
Condylar cutoff sign (ratio)	0.74 ± 0.11	0.81 ± 0.04	1.992*	0.049

Values are presented as mean ± SD or n (%). *t value; †χ^2 value. SD: Standard deviation.

Table 3: The inter- and intra-observer reliability for each variable

Variables	Intra-class correlation coefficient (95% CIs)	
	Inter-observer	Intra-observer
Later joint space	0.82 (0.77–0.87)	0.93 (0.90–0.96)
Height of lateral tibial spine	0.81 (0.73–0.87)	0.92 (0.88–0.94)
Height of the fibular head	0.85 (0.80–0.91)	0.97 (0.95–0.99)
Obliquity of the lateral tibial plateau	0.76 (0.69–0.84)	0.89 (0.85–0.93)
Condylar cutoff sign	0.87 (0.83–0.92)	0.95 (0.91–0.98)

*CI*s: Confidence intervals.

indirect signs on plain radiographs. They discovered that there were significant differences in the lateral joint space and height of fibular head between the two groups. Choi *et al.*[6] quantitatively compared radiographic findings of symptomatic discoid lateral meniscus of 91 knees in children with other age- and sex-matched controls and found a significant difference in the mean height of the lateral tibial spine, lateral joint space distance, height of the fibular head, and obliquity of the lateral tibial plateau between the two groups. They recommended that MRI scans should be considered in child patients with knee joint pain in case of characteristic radiographic findings of discoid lateral meniscus, particularly of elevated fibular head (<15 mm) or widened lateral joint space (>8 mm). Previous studies found that those anatomical variables were special in knees with discoid lateral menisci.[6,10-11] The aim of this article was to explore the relationship between those anatomical variables and meniscal tears. In the study, 96% of knees in both groups showed more than one characteristic radiographic finding of a discoid lateral meniscus. This is mainly because all patients enrolled in this study were selected beforehand with a discoid lateral meniscus. These findings clearly showed that there are some characteristic anatomical variants of knees with a discoid lateral meniscus, although there is also debate on the value of these variants. It is most likely because there are no effective and sensitive quantitative indicators for these variants. With more studies in this field and better measuring methods, the true value of characteristic radiographic findings in the detection of discoid lateral meniscus can be realized.

It is well known that the discoid menisci are more prone to tear and degeneration than normal menisci. In the study of Rohren *et al.*,[4] a large population of 1250 knees were investigated using MRI, and the frequency of solitary lateral meniscal tear in patients with discoid lateral meniscus was observed to be almost twice as high as in patients without a discoid lateral meniscus (20% vs. 11%). Most investigators suggested that the predisposition of the discoid lateral meniscus to tear was due to the anomalous shape, thickness, and poor vascularization.[4,21,22] Furthermore, there are also some etiological factors related to meniscal tears, such as sex, age, sports, sides of limbs, and degeneration.[14-16] Considering that these anatomical knee variants inevitably change the biomechanics of discoid lateral menisci, we have reason to propose that these variants are more or less attributed to the predisposition to tear of a discoid lateral meniscus. As a result of the study, the condylar cutoff sign shows a relationship with the tear of the discoid lateral meniscus. The prominence ratio of the lateral and medial femoral condyles in the torn group was significantly smaller than that in the control group, which suggests that the lateral

Table 4: Radiographic dimensions according to the types of discoid lateral meniscus

Variables	Complete type (n = 69)	Incomplete type (n = 56)	Statistical values	P
Lateral joint space (mm)	7.06 ± 1.92	6.76 ± 2.03	1.703*	0.092
Height of lateral tibial spine (mm)	6.65 ± 1.44	6.82 ± 1.34	0.674*	0.502
Height of the fibular head (mm)	12.38 ± 2.96	12.59 ± 2.65	0.418*	0.677
Obliquity of the lateral tibial plateau (°)	16.59 ± 1.64	16.42 ± 1.86	0.533*	0.595
Squaring of the lateral femoral condyle (%)	28 (40.6)	22 (39.3)	0.022†	0.883
Cupping of the lateral tibial plateau (%)	22 (31.9)	22 (39.3)	0.746†	0.389
Lateral femoral condylar notch (%)	5 (7.3)	3 (5.4)	0.184†	0.668
Condylar cutoff sign (ratio)	0.81 ± 0.47	0.81 ± 0.40	0.474*	0.635

Values are presented as mean ± SD or n (%). *t value; †χ^2 value. SD: Standard deviation.

femoral condyles of the torn group are fewer rounds and more sharp. During the activity of the knees, less round femoral condyles might lead to a local stress concentration on vulnerable discoid menisci, which can account for the meniscus injury. This result indicated that the cutoff sign might be valuable in the prediction of a discoid lateral meniscus to tear. Patients with discoid lateral meniscus with a condylar prominence ratio of <0.78 are prone to get a discoid lateral meniscus tear. With regard to the other anatomical knee variants, there is no significant difference between the torn and the control groups. These variants appear to have very little or no influence on the predisposition of discoid lateral meniscus to tear.

Thus far, there have been few reports studying the correlation between anatomical knee variants and the types of discoid lateral menisci. In this study, we tried to find whether there were some differences in the anatomical dimensions between complete and incomplete discoid menisci. Consequently, no significant difference was found between the two types, which was similar to the results obtained by Kim *et al*.[13] The lateral joint space of complete discoid lateral menisci (7.06 ± 1.92 mm) appeared larger than that of incomplete menisci (6.76 ± 2.03 mm), although this difference was not significant. Since the complete discoid lateral menisci are wider and thicker than incomplete menisci, it appears reasonable that they have a trend of larger lateral joint space on radiographs.

Patients in the control group had untorn discoid lateral menisci. Their most common complaint was knee soreness after activities. However, physical or imaging examinations often could not find any positive evidence. The real cause of their symptoms was not clear. We think it might be because of the mechanical changes in knees with discoid lateral meniscus which lead to overload on local cartilage. Nowadays, MRI has been a common method of imaging examination because of its clear display of soft-tissue lesions. However, it also costs more and is far less popular than radiograph. Radiograph is still the first choice in clinic. The anatomical variances on radiographs studied in this study could provide indirect evidences for the diagnosis of discoid lateral meniscus.

There were some limitations in this study. First, all patients in the torn group underwent arthroscopic surgery for a torn discoid lateral meniscus, suggesting that all patients obtained a symptomatic discoid lateral meniscus tear. Patients with asymptomatic discoid lateral meniscus tears were not considered in this study. Second, there was a relatively small sample in the control group. This was mainly because there were generally no remarkable symptoms in patients with intact discoid lateral menisci. In this study, all participants in the control group were incidentally identified as having an intact discoid lateral meniscus on MRI findings. Third, the types of meniscal tears were not investigated and analyzed. The discoid menisci were not detected in the contralateral knee, giving no chance of comparison between the affected and unaffected knees in one patient. In addition, cases with different limbs or unmatched ages or other diseases were excluded from the study to increase the comparability between groups. Furthermore, variances in most of these characteristic radiographic dimensions are generally small between groups. Thus, it is more difficult to identify significant differences in a study with small cases. A much larger group of patients should be enrolled in the future studies. Finally, the tunnel-view radiograph is needed to measure the condylar cutoff sign. It is difficult for this special view radiograph to be popularized.

In conclusion, the condylar cutoff sign on the tunnel view of the radiograph would be helpful in predicting meniscal tears in adult patients with a discoid lateral meniscus. If patients with a discoid lateral meniscus have a cutoff sign of less condylar prominence ratio, there is a higher risk of meniscal tear in these people, and further investigations, such as MRI, should be recommended.

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Conflicts of interest

There are no conflicts of interest.

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