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ORIGINAL STUDY

What is the reason of the high fibular head in the Discoid Lateral Meniscus?

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The purpose of this study was to assess the factors associated with high fibular head in symptomatic discoid lateral meniscus (DLM). Eighty-seven patients with complete DLM (discoid group) and 80 normal subjects (control group) were included prospectively. Plain X-rays and MRI were analyzed for level and angle of the fibular head and thickness and type of Wrisberg ligament. Multivariate regression analysis was performed to find the factors associated with levels of the fibular head and DLM. The angle of the fibular head was the only factor associated with level of the fibula in the discoid group (odds ratio : 3.0, p=0.007). The 13.6mm cut off value for fibular level had 70.5% sensitivity and 77.0% specificity for diagnosis of DLM. A high fibular head was associated with larger angle and type of fibular head.
Level of evidence : Level II

Keywords : Knee ; discoid lateral meniscus ; high fibular head ; Wrisberg ligament ; X-ray ; magnetic resonance imaging

INTRODUCTION

Discoid lateral meniscus (DLM) is the most com-mon congenital anomaly of the meniscus, with reported prevalence in Western countries of 0.4-4. 6 % and a much higher incidence in the Asian patient population (13.4-17.9%) *(9,12,15)*. Although asymptomatic DLM does not require treatment, some DLM cases have an associated tear, which results in symptoms *(1,7,12,15)*.

Magnetic resonance imaging (MRI) is usually conclusive, and plain X-ray is only supplementary for diagnosing DLM *(7, 18)*. Characteristic findings of DLM on plain X-rays are often subtle but include a widened lateral joint line, squaring of the lateral femoral condyle, cupping of the lateral tibial plateau, mild hypoplasia of the tibial spine, and high fibular head *(1,7,12)*. However, several researchers have demonstrated that characteristic

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Table 1. — The mean and standard deviation (SD) values of each parameter in the discoid lateral meniscus (discoid) and control groups as measured in session 1

		Discoid group (DLM) (n=87) Mean ± SD	Control group (n=80) Mean ± SD	p-value
Age		40.9 ± 13.0	39.9 ± 11.4	0.603
Sex	Male	31	30	0.802
	Female	54	50	
Level of fibular head (mm)		11.06 ± 3.28	14.93 ± 3.00	0.000
Angle of fibular head in lateral X-ray (º)		19.10 ± 6.52	15.39 ± 6.11	0.000
Angle of fibular head in MRI (º)		18.24 ± 6.78	15.74 ± 6.38	0.016
Thickness of Wrisberg ligament (mm)		2.53± 0.56	1.91± 0.58	0.000
Type of Wrisberg ligament†	I	40	11	0.000
	II	41	54	
	III	6	15	
Type of fibular head†	I	14	20	0.153
	II	73	60	
Presence of high fibular head	+	60	21	0.000
	-	27	59	

† Number of cases of each type (%).

X-ray findings in DLM could offer an inexpensive and efficacious pre-screening tool for DLM prior to utilizing MRI *(4,7,8,12)*. In particular, a high fibular head is the most common finding that has a specific cutoff value for diagnosis of DLM *(14)*. To the best of our knowledge, there has been no published study investigating potential or associated factors with high fibular head in DLM patients. In addition, there have been studies reporting a strong association between DLM and a high-riding Wrisberg ligament that is anatomically located relatively close to the fibular head *(10,11,16)*.

The purpose of this study was to investigate the relationships between high level of fibular head and several potential factors considered to be relevant to it. The hypothesis of this study was that the fibular head is significantly associated with its morphology, and that a high-level fibular head is associated with a high-riding and thick Wrisberg ligament.

MATERIALS AND METHODS

This was a prospective observational study performed between 2012 and 2016, and was approved by institutional review board of our organization. Eighty-seven consecutive patients who underwent arthroscopic surgery for symptomatic, complete type DLM (discoid group) were enrolled in the study. The inclusion criteria were as follows : *(1)* diagnosed with complete type DLM based on MRI before arthroscopic surgery, *(2)* the diagnosis was confirmed by intraoperative findings, and *(3)* age 18 or older. Patient demographics are summarized in Table 1.

X-ray Evaluation

With plain X-ray evaluation, angle, level, and type of fibular head were assessed on true anteroposterior and lateral X-rays. (Fig. 1a, b) Fibular head level was defined as high if the distance from the joint line to the fibular head tip was less than 13mm and low if the distance was greater than 13mm. Fibular head angle was measured anteroposteriorly based on a line perpendicular to the fibular shaft axis. Type of fibular head was classified according to angle into the following two types : flat (Type I) if the angle was less than 10º on the lateral view and elevated (Type II) if the angle was greater than 10º. Because the mobility and joint surface area of the proximal tibiofibular joint are susceptible to fibular morphology, it was classified as a flat or elevated type. The proximal tibiofibular joint of elevated type has been reported to be strongly associated

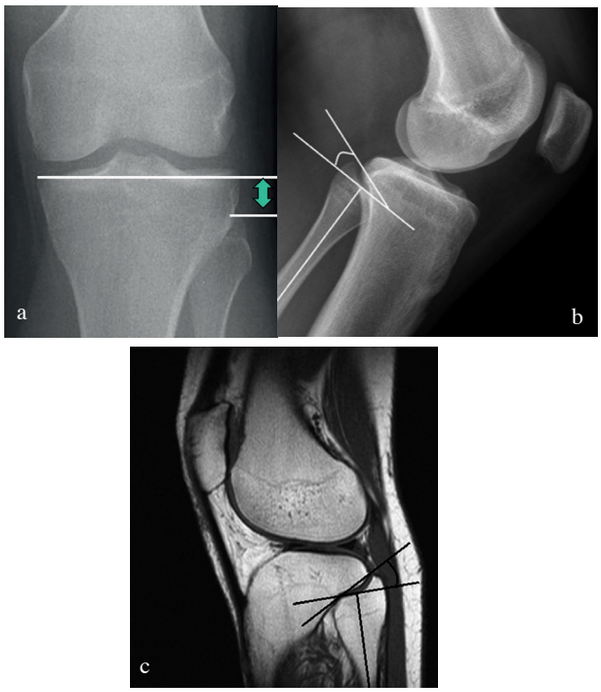

Figure 1. — Measurement of fibular head : a) Level, b) angle, and c) angle on mid-sagittal MRI.

with knee injury and reduced rotatory mobility, as volume of articular cartilage and joint surface area are small *(6,19)*.

On MRI evaluation, the angle of the fibular head and the thickness and type of Wrisberg ligament were examined. The angle of the fibular head was measured on the sagittal view anteroposteriorly based on a line perpendicular to the fibular shaft axis (Fig. 1c). The thickness of the Wrisberg ligament was measured on MRI mid-sagittal view. Assuming two straight lines along the axis of the Wrisberg ligament (along its upper and lower margin), the distance between these two perpendicular lines was measured. The types of femoral attachment of the Wrisberg ligament were based on the classification by Cho et al. *(3)*. The attachment site was the medial femoral condyle in Type I, the proximal half of the PCL in Type II, and the distal half in Type III. Type I Wrisberg ligament was defined as a high-riding Wrisberg ligament, and Types II and III were defined as low-riding Wrisberg ligaments.

Statistical Analysis

Results were analyzed using IBM SPSS Statistics software (IBM, Armonk, NY, USA), and power analyses were performed using the G*power 3.1.5 program (Universitat Dusseldorf, Northrhine-Westphalia, Germany).

The primary outcome measurement was the adjusted R^2 value of the multivariate linear regression analysis with an a error of 5% and b error of 20% for detecting a significant difference. The observed statistical power was calculated as 0.9904041 in multivariate linear regression analysis of a fibular level model, based on an effect size of 0.2180268 by Cohen's f^2 equation using the adjusted R^2 value.

For comparison of mean values, independent t tests were used to identify differences in demographics and measurements. Based on MRI and plain X-ray findings, multivariate linear regression analysis was used to assess the roles of the predictor variables (Table 1) in forecasting outcome variables (level of the fibular head) using the stepwise method.

Moreover, to determine if level of the fibular head and presence of DLM were associated with the Wrisberg and fibular types, the patients were divided into two groups for statistical analysis : positive (less than 13mm) or negative (more than 13mm) findings ; discoid or control group. The associations between DLM, fibular head level, types of Wrisberg and fibular head type were analyzed with Pearson's chi-square test and linear by linear chi-square test. Stepwise binary logistic regression analysis was performed using the results of the Akaike information criterion (AIC) to find the risk factors of DLM and high level of the fibular head. Receiver-operating characteristic (ROC) curves were also plotted to evaluate diagnostic accuracy and cut-off values for DLM using the predictor variables. Statistical significance was set at $P \leq 0.05$. For inter- and intra-observer reliability of the preoperative MRI, a test-retest was performed by two independent radiologists at two weeks from the first measurement of intraclass correlation coefficient (ICC) for consistency.

Table 2. — Predictive factors for level of fibular head on multivariate linear regression analysis in DLM patients, in whom smaller value means high fibular head

Factor	B-Value±S.E	95% Confidence Interval of B	P value	Adjusted R^2 Value
Angle of fibular head in MRI	-0.197 ± 0.049	-0.295 - -0.099	0.000	0.179
Age	-0.082 ± 0.026	-0.133 - -0.031	0.002	
Constant term	18.026 ± 1.592		0.000	

Table 3. — Factors of presence of a high fibular head and DLM

		Presence of High Fibular Head		P-value¶	RR¶ (95%CI)
		+	-		
Sex	Male	21	10	0.854	-
	Female	39	17		
Type of fibular head	I	6	8	0.021	2.195 (1.210-3.985)
	II	54	19		
Type of Wrisberg ligament	I	26	14	0.195	-
	II	28	1		
	III	6	0		
		Presence of DLM		P-value¶	RR¶ (95%CI)
		+	-		
Sex	Male	31	30	0.802	-
	Female	56	5		
Type of fibular head	I	14	20	0.153	-
	II	73	60		
Presence of high fibular head	+	60	21	0.000	2.359 (1.683-3.308)
	-	27	59		
Type of Wrisberg ligament	I	40	11	0.000	-
	II	41	54		
	III	6	15		

P-value¶ : Pearson's chi square test or linear by linear test ; RR¶ : Relative risk

Table 4. — Factors associated with high fibular head and DLM on logistic regression analysis

Factor	Odds Ratio	B-Value ± S.E	95% Confidence Interval	P value
Risk of presence of high fibular head in DLM patients				
Age	1.054	0.052 ± 0.023	1.008-1.102	0.022
Angle of fibular head on MRI	1.186	0.171 ± 0.049	1.078-.305	0.000
Constant term		-4.539 ± 1.529	-	0.003
Risk of DLM				
Type of Wrisberg ligament (Reference: Type III)				
I	8.139	2.097 ± 0.875	1.466-45.187	0.017
II	3.341	1.206 ± 0.766	0.745-14.983	0.115
III	-	-	-	0.049
Thickness of Wrisberg ligament (mm)	6.648	1.894 ± 0.453	2.738-16.142	0.000
Level of fibular head (mm)	0.579	-0.547 ± 0.101	0.478-0.705	0.000
Constant term		1.748 ± 1.337	-	0.191

RESULTS

The discoid group had a significantly lower mean level of fibular head (11.1 mm) (high fibular head) than that of the control group (14.9 mm) (Table 1, $p<0.0001$). The discoid group had a significantly larger mean angle of the fibular head on both plain X-ray and MRI than that of the control group (Table

1, p<0.0001). Furthermore, significant differences in thickness of the Wrisberg ligament and type of Wrisberg ligament distinguished the two groups (p<0.0001). A high fibular head, defined as 13mm, was more strongly associated with DLM (odds ratio (OR) : 6.243, 95% CI : 3.182-12.251) than other factors (Table 1).

In multivariate analysis, the fibular head angle on MRI was the predictive factor for the level of the fibular head in the discoid group (Table 2). Increased angle of the fibular head was significantly correlated with high fibular head.

Factors related to high fibular head and DLM using Pearson's chi squared test are summarized in Table 3. Patients that had Type 2 fibular head presented more often with a high fibular head level (relative risk (RR) : 2.195, p=0.021). The presence of DLM was associated with a high fibular head level (RR : 2.359, p=0.000) and Type 1 Wrisberg ligament (p<0.000).

Factors associated with a high fibular head and DLM using binary logistic regression analysis are summarized in Table 4. The fibular head angle on MRI was significantly associated with a high fibular head level in DLM patients. Type and thickness of the Wrisberg ligament and level of fibular head were also significantly associated with presence of DLM. Increased thickness of the Wrisberg ligament and higher fibula head were correlated with the increased risk of DLM. Moreover, patients with Type I Wrisberg ligament demonstrated greater risk for presence of DLM than patients with Type III Wrisberg ligament (OR : 8.139, p=0.017).

To acquire the diagnostic accuracy of each factor, the area under the ROC curve (AUC) was also calculated for presence of high fibular head and DLM (Table 5). Angle of the fibular head on X-ray and MRI and thickness of the Wrisberg ligament were statistically significant (Fig. 2a.) Fibular head level had the largest AUC (AUC : 0.807, p=0.000) for diagnosis of DLM (Fig. 2b), and the 17.7° cutoff value for fibular head angle on X-ray demonstrated 64.4% sensitivity and 61.3% specificity. The 13.6mm cutoff value for fibular head level demonstrated 70.5% sensitivity and 77.0% specificity regarding diagnosis of DLM.

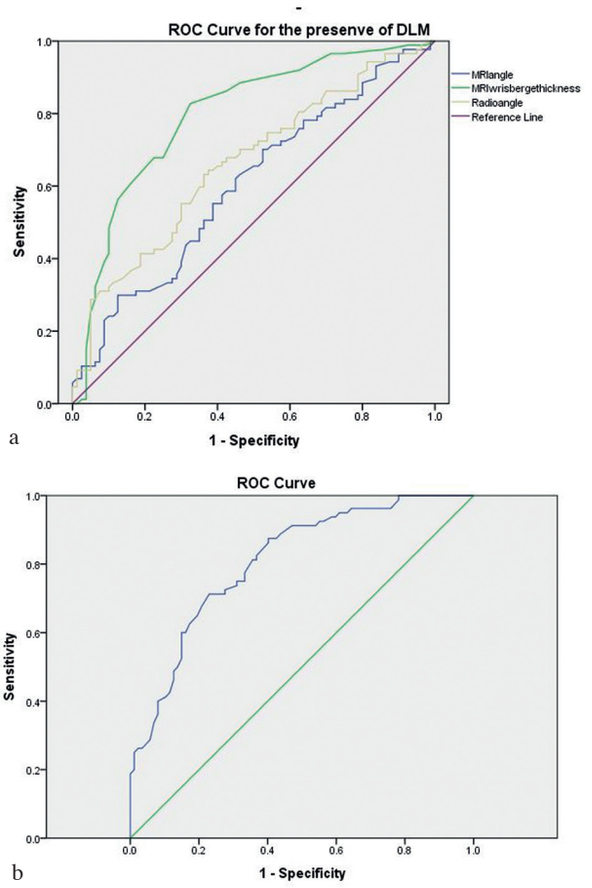

Figure 2. — The receiver-operating characteristic (ROC) curves to diagnose DLM. The purple line is reference. a) Thickness of the Wrisberg ligament on MRI showed the largest area under the ROC (AUC) except for level of the fibular head. b) The ROC curve for level of fibular head to diagnose DLM.

The ICC for intra- and interobserver reliability showed a range of 0.794-0.975, indicating high agreement between evaluators.

DISCUSSION

The most important finding of this study was that the fibular head level was significantly different between the discoid group and the control group. Additionally, in patients with complete type DLM, high fibular head level was associated with type of fibular head and an increased posterior slope of the fibular head. A thicker Wrisberg ligament and a Type I high-riding Wrisberg ligament showed a statistically strong correlation with DLM.

Table 5. — Area under the ROC curve, sensitivity, and specificity of each factor

	AUC	95% CI of AUC	P-value*	Youden index	Criteria value	Sensitivity	95%CI of sensitivity	Specificity	95% CI of specificity
	Presence of DLM								
Angle of fibular head on X-ray	0.662	0.585-0.733	0.0001	0.2697	17.7	64.4%	53.4-74.4	61.3%	49.7-71.9
Angle of fibular head on MRI	0.602	0.517-0.688	0.0242	0.1755	15.3	70.4%	60.4-79.5	46.5%	34.8-57.8
Thickness of Wrisberg ligament	0.796	0.727-0.866	0.000	0.5071	2.0	82.8%	73.2-90.0	67.95%	56.4-78.1
Level of fibular head	0.807	0.742-0.872	0.000	0.4572	13.6	70.5%	59.1-90.3	77.0%	66.8-85.4

Characteristic DLM findings most commonly observed on plain X-ray include increased joint space on the lateral side, cupping of the lateral tibial plateau, marginal osteophytes in the peripheral rim of the lateral tibial plateau, flattening of the lateral femur, hypoplasia of the tibial eminence, and high fibular head *(1,3,7,12,20)*. A thickening and enlarged lateral meniscus (LM) may cause widening of lateral joint space and osteophytes in the peripheral rim. However, there are no hypotheses or studies on the potential factors related to high fibular head. The current study found that the angle of the fibular head was significantly different between the DLM and the control groups on plain X-ray and MRI evaluation (Table 1). As shown in previous studies, the level of the fibular head was significantly different between the discoid group (11.06 mm) and the control group (14.93 mm) (Table 1). Additionally, in patients with DLM of the complete type, the correlation between elevation and the angle of the fibular head was significant on X-ray findings (Table 2). In a study that compared plain X-rays of 70 DLM patients and a control group, Kim et al. *(14)* argued that plain X-ray findings are the most useful screening test, and that a high fibular head level and an increase in lateral joint space over 5 mm are specific cutoff values. As mentioned above, the fibular head angle was classified into two types in this study. Generally, the slope of the fibular head's posterior side increases on lateral view. Accordingly, a high fibular head level shows a further increased posterior slope on lateral view of plain X-ray. Comparison of fibular head type between the DLM and the control groups did not show a statistically significant difference. However, if a high fibular head was present, there was increased risk of Type 2 fibular head, as peaked type (Table 3). Therefore, it can be assumed that a high fibular head level is associated with increased angle of the fibular head posteriorly.

Study findings regarding thickness and type of Wrisberg ligament were consistent with previous findings. A thicker Wrisberg ligament and a Type I high-riding Wrisberg ligament showed statistically strong correlation with DLM (Table 4). A normal LM is attached loosely at the lateral joint capsule ; thus, the anterior and posterior meniscofemoral ligaments play a role in strengthening the anterior and posterior attachments of the LM *(3,12,13)*. Of those, the posterior meniscofemoral ligament, i.e., the Wrisberg ligament, is one of the most important accessory ligaments and the main stabilizer of the LM. Discoid lateral menisci often have poorer vascularity than normal menisci and are more susceptible to tears *(2,5,13)*. The Wrisberg variant lacks the normal posterior coronary ligament and capsular attachments. Instead, the posterior horn of the lateral meniscus is mobile, occasionally subluxing into the joint *(10,11,16)*. MRI also can be used to assess the Wrisberg variant and tearing of the discoid meniscus and is useful for preoperative planning and evaluating prognosis *(3,10,11,16,19,20)*. Patients with a complete discoid lateral meniscus have a thicker and higher-riding Wrisberg ligament than patients with a non-discoid meniscus. This thick and high-located Wrisberg ligament results in a wider excursion of lateral meniscus during flexion and extension, and the lateral meniscus is easily damaged with repetitive motion. Kim et al. *(10)* found that a thicker Wrisberg ligament with a higher location increased the burden to the lateral

meniscus and may stimulate formation of a complete DLM. Wrisberg variants are more likely to become symptomatic at an early age. Moser et al. *(1)* found that lack of meniscotibial attachment allows for potential hypermobility of the posterior horn of the lateral meniscus. However, the hypothesis that Wrisberg ligament type is associated with level of the fibular head was not statistically supported in the present study. High fibular head showed a statistically significant association only with the elevated type of fibular head (Type II).

Limitations of the current study must be addressed. First, the number of enrolled patients was small. Second, only Asian patients participated. Comparative investigation in a Caucasian population may show differences. Finally, the study population was limited to adults over age 18 ; thus, there could be differences at younger ages *(17)*

CONCLUSIONS

With plain X-ray findings of patients with DLM complete type, high level of the fibular head showed a statistically significant correlation with the fibular head angle. It is assumed that a high fibular head is associated with a fibular head angle that is increased posteriorly and an elevated fibular head type, which is prone to injury.

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