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Original article

Factors associated with bilateral discoid lateral meniscus tear in patients with symptomatic discoid lateral meniscus tear using MRI and X-ray

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ABSTRACT

Background: The incidence of bilateral discoid lateral meniscus (DLM) is as high as 73 to 85%, and associated contralateral meniscus tears ranged from 4 to 33% in symptomatic surgical DLM. The goal of the study was analyzing the factors that predict contralateral presence and tearing of DLM in patients who underwent surgery for symptomatic DLM. Our hypothesis was that there is a significant correlation between operative DLM properties and the incidence of bilateral DLM with associated contralateral meniscus tears. These properties include tear patterns, younger patient age, and characteristic X-ray findings.
Patients and Methods: This prospective study included 76 patients who underwent arthroscopic surgery for symptomatic DLM. The contralateral knees were evaluated with X-ray and MRI. Based on the MRI findings, DLM was categorized into three types, and tear patterns were analyzed. The characteristic X-ray findings were evaluated as follows: (1) high fibular head, (2) squared-off appearance of the lateral femoral condyle, (3) cupping of the lateral tibial plateau, (4) widened femorotibial joint space, (5) hypoplasia of the lateral intercondylar spine, (6) notching of the LFC. The number of characteristic X-ray findings (0/1/more than 2) was noted. Binary logistic analysis was performed to find the factors that predict the presence and tear of contralateral DLM.
Results: MRI of contralateral knees revealed 43 cases (57%) of complete DLM, 25 cases (33%) of incomplete DLM, and 8 cases (11%) of normal meniscus. Meniscus tears were found in 29 cases (38%) in the contralateral knee. X-ray of the contralateral knee revealed that 27 patients (36%) had one and 24 patients (32%) had two or more characteristic X-ray findings. On logistic regression analysis, the associations between contralateral knee meniscal tear and the presence of one or more than two characteristic X-ray findings were statistically significant (OR: 16.5, $p = 0.028$; OR: 264.0, $p = 0.000$, respectively).
Discussion: The number of characteristic X-ray findings in the contralateral knee is a significant predictive factor for contralateral DLM type and/or tear. Symptomatic DLM patients with characteristic X-ray findings should be carefully evaluated for contralateral DLM and meniscal tears.
Level of evidence: III, prospective diagnostic study of consecutive patients.

1. Introduction

Discoid lateral meniscus (DLM) is the most common anatomical variation of the knee joint in pediatric patients, especially in Asian populations [1,2]. The incidence of bilateral DLM was previously reported to range from 5 to 20% of cases in patients that underwent surgery for symptomatic DLM. However, that incidence has recently been reported to be as high as 73 to 85% [3–7]. Associated contralateral meniscus tears ranged from 4 to 33% in patients subject to surgery for symptomatic DLM [4–9]. No research on potential predictive factors for contralateral meniscus state and tears has been reported in patients with surgical DLM. Early detection and monitoring of the contralateral DLM tear is required to avoid clinical worsening.

One purpose of this study was to find the factors associated with the presence of contralateral DLM in symptomatic, surgical DLM cases. Another purpose was to assess the presence of contralateral DLM tear or hiatus widening using X-rays and MRI. Our hypothesis was that there is a significant correlation between operative DLM properties and the incidence of bilateral DLM with associated

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Table 1
Results of characteristic X-ray findings of DLM in a contralateral knee joint.

Characteristic X-ray findings	No. of knees	Proportion (%)[c]
High fibula head	46	61
Squared-off appearance of LFC[a]	5	7
Cupping of LTP[b]	3	4
Widened lateral joint space	6	8
Hypoplasia of the lateral spine	6	8
Notching of LFC	21	28
Total	51	67

[a] LFC = lateral femoral condyle.
[b] LTP = lateral tibia plateau.
[c] Proportions: each case/76.

contralateral meniscus tears. These properties include tear patterns, younger patient age, and characteristic X-ray findings.

2. Materials and Methods

2.1. Patient Demographics

A prospective cohort study was performed on a population of 104 patients who underwent arthroscopic surgery for symptomatic, complete DLM between 2011 and 2016. The study was approved by the Institutional Review Board of the hospital (No. KHNMC2013-01-047-2013). Inclusion criteria included the presence of symptomatic complete-type DLM knees in MRI, for which arthroscopic surgery was performed. After arthroscopy, contralateral MRI and standing X-ray evaluations were also performed to including patients. Patients with a history of knee joint surgery were excluded as were those with symptoms in both knees. Twenty-eight patients were excluded. Patients presenting with asymptomatic contralateral DLM tears were treated conservatively unless the DLM tear was associated with severe shifting.

To find the factors associated with the presence of contralateral DLM and its tear, the characteristic DLM X-ray findings, age, sex, type of shift and tear on operated knees, hiatus widening presence, chondral lesion presence, surgical method, Tegner score and symptom duration were assessed.

A single experienced surgeon (SHL) performed all surgeries. Partial meniscectomy was performed in 20 patients, partial meniscectomy with repair in 47 patients, and subtotal meniscectomy in 9 patients.

2.2. MRI Evaluations

MRI examinations were performed on a 3.0T scanner (Achieva; Phillips Medical Systems, Netherlands) for both knees. Each surgical DLM was categorized according to shifting meniscus morphology. Morphological shift types included:

- anterocentral;
- posterocentral;
- central, and;
- no shift [10,11].

Based on MRI findings and arthroscopic findings, the tear patterns were categorized as:

- horizontal;
- horizontal and peripheral, and;
- peripheral corner loss [11].

The size of the popliteal hiatus was also evaluated on MRI. Popliteal spaces estimated to be larger than 5 mm on both coronal and sagittal images suggested significant popliteal hiatal widening. Chondral lesions over ICRS grade 3 were also evaluated by MRI and arthroscopy.

2.3. X-ray Evaluations

Simple weight-bearing X-rays with patella forwarding position were performed on all patients on the contralateral side. Six characteristics DLM X-ray findings were evaluated. These included:

Table 2
Factors associated with contralateral discoid lateral meniscus shape by Chi^2 test.

Factors		Complete(43)	Incomplete(25)	Normal(8)	*p* value
Age	≤ 16yrs	9	9	3	0.328
	> 16yrs	34	16	5	
Sex	Male	16	13	3	0.473
	Female	27	12	5	
Symptom duration	≤ 6 months	25	15	4	0.882
	> 6months	18	10	4	
Contralateral DLM	0	6	15	4	< 0.001/ < 0.001*
X-ray findings	1	16	7	4	
	> 2	21	3	0	
MRI shift classification	I	14	7	3	0.385
of the operated knee[a]	II	15	8	0	
	III	5	6	3	
	IV	9	4	2	
Meniscus tear pattern	I	16	1	2	0.012
of the operated knee[b]	II	16	16	6	
	III	11	8	0	
Chondral lesion of the	No	34	21	7	0.793
operated knee	Yes	9	4	1	
Surgical method[c]	I	13	3	4	0.181
	II	24	19	4	
	III	6	3	0	
Pre-injury Tegner score		6.7 ± 2.0	6.9 ± 1.7	8.0 ± 1.4	0.198**

[a] I: anterocentral shift type. II: posterocentral shift type, III: central shift type, IV: no shift type.
[b] I: horizontal, II: horizontal and peripheral tear, III: peripheral corner loss.
[c] I: partial meniscectomy, II: partial meniscectomy with repair, III: subtotal meniscectomy.
* *p*-value for linear by linear association test.
** *p*-value for one-way ANOVA.

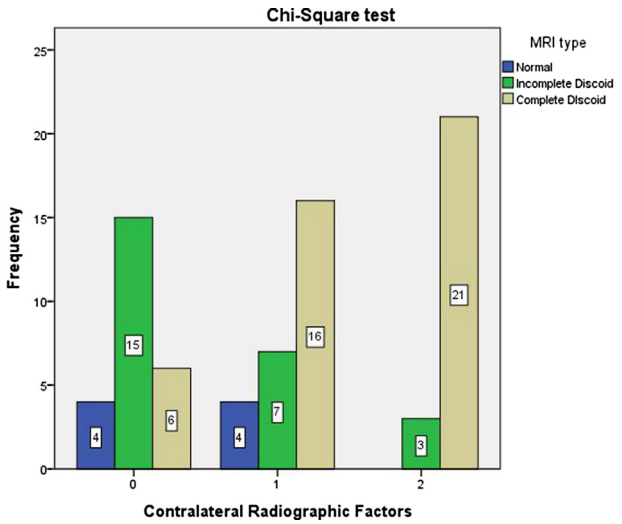

Fig. 1. Distribution of lateral meniscus shape by MRI evaluation of the contralateral knee joint according to the contralateral X-ray findings.

- high fibular head (less than 13 mm from joint);
- squared-off appearance of the lateral femoral condyle (LFC);
- cupping of the lateral tibial plateau (LTP);
- widened tibiofemoral joint space;
- hypoplasia of the lateral intercondylar spine and;
- notching of the LFC [12].

The tibial inclination was not evaluated.

2.4. Statistical analysis

Data were analyzed using SPSS version 20.0 (SPSS, Inc., Chicago, IL, USA) and the G*power program (ver 3.1.5). Factors associated with contralateral DLM type and tear were analyzed with a chi-square test, independent *t*-tests or one-way analysis of variance (ANOVA). Binary stepwise logistic regression analysis was performed to evaluate the risk of contralateral DLM or tear presence. The predictive factors were age, sex, symptom duration (greater or less than 6 months), types of shift and tear, hiatus widening presence, chondral lesion presence, surgical method, Tegner score, and number of characteristic X-ray findings.

Sample size calculation was based on the difference in proportion results of Ahn et al. [7]. These data were 82% of meniscus tears in operated knees and 33% of meniscus tears in contralateral knees; α error was set at 5% and β error at 10% to detect a significant difference of proportion. Based on these calculations, the required sample size was 46 cases for this study.

Statistical significance was set at $p < 0.05$. All radiographic studies were reviewed by 2 musculoskeletal radiologists, with 2 weeks interval. The inter- and intra-observer reliability of the measurements were assessed using the intraclass correlation coefficient (ICC).

3. Results

3.1. Characteristic X-ray findings of the contralateral knee

On X-ray evaluation of the contralateral knees, 51 patients (67%) had at least one characteristic X-ray finding and 24 (47%) had two or more (Table 1).

3.2. Predictive factors for presence of DLM in the contralateral knee

On MRI evaluation of the contralateral knees, 68 cases (90%) of bilateral DLM were observed. Forty-three cases (57%) were complete DLM, 25 cases (33%) were incomplete DLM, and 8 cases (10%) were normal.

Analysis of the association between the predictive factors and type of DLM in the contralateral knee is presented in Table 2

Table 3
Factors associated with a meniscus tear/hiatus widening in the contralateral knee by Chi² test.

Factors		Meniscus/hiatus widening (34)	No meniscus tear (42)	*p* value
Age	≤ 16yrs	9	12	0.839
	> 16yrs	25	30	
Sex	Male	14	18	0.883
	Female	20	24	
Symptom duration	≤ 6 months	18	26	0.431
	> 6months	16	16	
Chondral lesion of the operated knee	No	26	36	0.301
	Yes	8	6	
Contralateral DLM X-ray findings	0	1	24	< 0.001/ < 0.001*
	1	11	16	
	> 2	22	2	
MRI shift classification of the operated knee[a]	I	10	14	0.576
	II	13	10	
	III	5	9	
	IV	6	9	
Meniscus tear pattern of the operated knee[b]	I	11	8	0.173
	II	13	25	
	III	10	9	
Surgical method[c]	I	9	11	0.349
	II	19	28	
	III	6	3	
High Fibular Height	Positive	30	19	< 0.001
	Negative	4	23	
Pre-injury Tegner score		6.9 ± 1.9	6.8 ± 1.8	0.815**

[a] I: anterocentral shift type. II: posterocentral shift type, III: central shift type, IV: no shift type.
[b] I: horizontal, II: horizontal and peripheral tear, III: peripheral corner loss.
[c] I: partial meniscectomy, II: partial meniscectomy with repair, III: subtotal meniscectomy.
* *p*-value for linear by linear association test.
** *p*-value for independent *t*-test.

and Fig. 1. Higher number of characteristic X-ray findings in the contralateral knee was associated with increasing incidence of complete DLM using linear by linear association analysis ($p < 0.001$). The operated knee tear pattern was statistically associated with the type of contralateral DLM ($p = 0.012$), as the incidence of horizontal tear in operated knee was higher in complete-contralateral DLM than other type of contralateral DLM.

3.3. Predictive factors for meniscus tear/hiatus widening in the contralateral knee

On MRI evaluation of the contralateral knees, a meniscal tear only was observed in 42.6% (29/68) of contralateral DLM, and overall 50% (34/68) of contralateral DLM presented with a meniscus tear/hiatus widening. There was no tear/hiatus widening in patients with normal contralateral menisci.

Analysis of the association between predictive factors and meniscus tear/hiatus widening in the contralateral knee is summarized in Table 3. The higher number of characteristic X-ray findings in the contralateral knee was associated with the increasing incidence of meniscus tear/hiatus widening. The association between meniscal tear/hiatus widening of the contralateral knee and the number of characteristic X-ray findings was statistically significant in logistic regression analysis. (Table 4, Fig. 2).

Among the characteristic X-ray findings, only higher fibular height was a statistically significant factor for meniscus tear/hiatus widening in the contralateral DLM ($p < 0.001$, odds radio (OR): 9.079 (95% CI: 2.715–30.365), relative risk: 4.133 [95% CI: 1.628–10.49]). (Table 3) The ICC values for radiographic reliability ranged from 0.83 to 0.91, indicating that raters were in good agreement.

Statistically significant differences in tears and shift patterns were observed according to age (Table 5). The posterocentral shift (type II) and the horizontal-peripheral tear (type II) in the operated knee predominated in the younger age group, but an even distribution among the types was observed in the older age group. Chondral lesions were found and meniscus surgery including repair was performed more often in the older age group (Table 5).

Older age was not associated with higher meniscus tear/hiatus widening incidence in this analysis; however, tear pattern, surgical method, and chondral lesion incidence were statistically different according to the age (Table 5).

4. Discussion

The most important finding of this study is that type of DLM and associated meniscal tear/hiatus widening of the contralateral (asymptomatic) knee were significantly associated with a higher number of positive characteristic X-ray findings. No relationship

Table 4
On logistic regression analysis, the association between meniscal tear/hiatus widening of the contralateral knee joint and X-ray findings.

Factor	Odds Ratio	B-Value ± S.E	95% Confidence Interval	*p* value
The risk of tear of contralateral discoid meniscus				
No DLM X-ray finding	Reference level			
Only one DLM X-ray finding	16.5	2.803 ± 1.093	1.936–140.609	0.01
Two or more DLM X-ray findings	264.0	5.576 ± 1.26	22.349–3118.575	< 0.001
Constant term		−3.178 ± 1.021		0.002

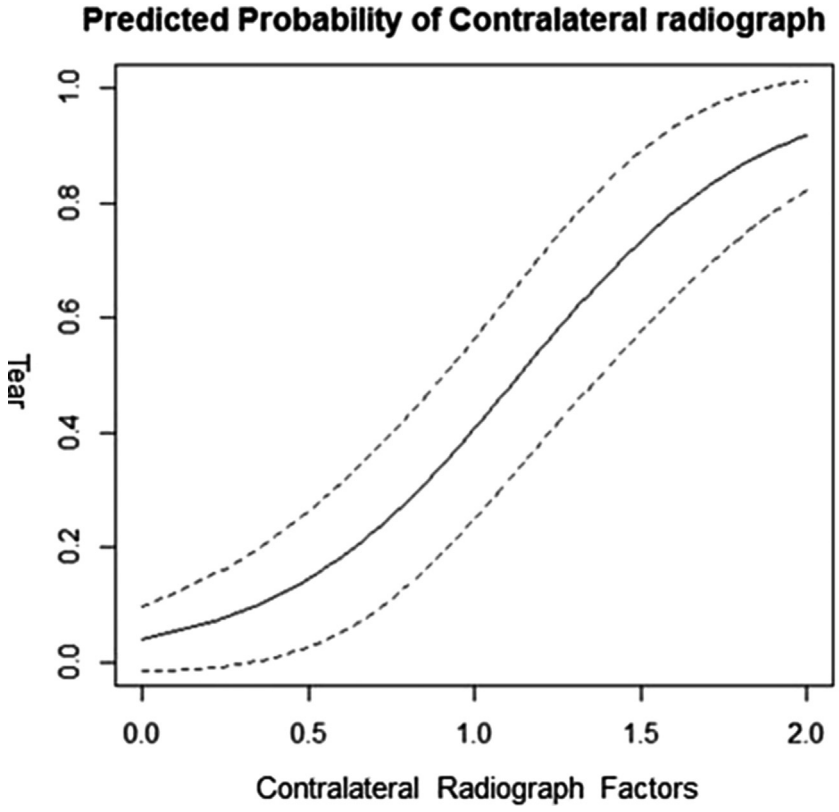

Fig. 2. The predicted probability for the contralateral X-ray findings (95% CI: dotted line).

Table 5
The DLM findings of the contralateral and operated knee according to the age.

		≤ 16yrs	> 16yrs	*p*-value
Mean age (mean ± standard deviation)		10.9 ± 3.0	40.3 ± 12.8	< 0.001
Sex	Male	11	21	0.262
	Female	10	34	
Contralateral DLM type of MRI	Normal	3	5	0.167
	Incomplete	9	16	
	Complete	9	34	
Contralateral tear/hiatus widening of DLM	No tear	12	30	0.839
	Tear/hiatus widening	9	25	
Chondral lesion of contralateral knee	No	21	49	0.179
	Yes	0	6	
MRI shift classification of the operated knee[a]	I	6	18	0.015
	II	11	12	
	III	4	10	
	IV	0	15	
Meniscus tear pattern of the operated knee[b]	I	1	18	< 0.001
	II	19	19	
	III	1	18	
Surgical method[c]	I	2	18	0.006
	II	19	28	
	III	0	9	
Chondral lesion of the operated knee	No	21	41	0.008
	Yes	0	14	

[a] I: anterocentral shift type. II: posterocentral shift type, III: central shift type, IV: no shift type.
[b] I: horizontal, II: horizontal and peripheral tear, III: peripheral corner loss.
[c] I: partial meniscectomy, II: partial meniscectomy with repair, III: subtotal meniscectomy.

between age or tear severity of DLM on the operative side and condition of the contralateral knee was noted. Patients with positive X-ray findings in the contralateral knee need to be counseled about the increased risk of contralateral DLM and tear/hiatus widening. Our hypothesis is confirmed.

Discoid meniscus is prone to injury by mechanical stress [13,14]. Symptoms may temporarily resolve or worsen, and, many asymptomatic cases have been found on MRI as grade III-signal change [5]. Bilateral DLM and meniscal derangement with degenerative changes should be evaluated carefully, even in the absence of significant symptoms [11–16] The results showed that older patients had more severe changes in the knee joint and generally required more complex surgical techniques (Table 5). However, the tear/hiatus widening of the contralateral asymptomatic DLM was not significantly related with age or tear pattern of the symptomatic, surgically repaired DLM. The risk of bilateral DLM and meniscal tear of the contralateral knee was increased if there was more than one characteristic contralateral knee X-ray finding.

Recent studies have reported an incidence of bilateral DLM as high as 84%–97% [4–17]. Previous studies involving arthroscopic evaluation of both knee joints showed a 79% incidence of bilateral DLM, and the bilateral DLM was of the same type in 65% of patients [4–6]. This study observed a 90% incidence of bilateral DLM, and the incidence of complete bilateral DLM was 57%.

Typical X-ray findings of DLM were elucidated in previous studies [12–18]. Recently, Choi et al. [18] concluded that a designated set of several X-ray findings would be a helpful screening tool for DLM. This study showed that 51 patients (67%) had at least one characteristic X-ray finding on the contralateral knee joint: 27 patients (53%) had one and 24 patients (47%) had two or more characteristic findings. The risk of tear/hiatus widening in contralateral asymptomatic DLM increased with the higher number of associated X-ray findings (Table 4). The association between meniscus tear of the contralateral asymptomatic DLM and higher fibular head was also statistically significant (OR: 9.079, $p < 0.001$).

Certain limitations of this study need to be addressed. First, the number of patients was relatively small making generalization to the entire population difficult. There could be different risk of tear/hiatus widening in contralateral DLM according to the higher number characteristic X-ray findings (e.g., 3–6 findings) if the higher number of patients included. Second, the results of this study may only be applicable to symptomatic Asian patients. Third, this study involved no clinical follow-up.

5. Conclusion

The number of characteristic X-ray findings in the contralateral knee is a significant predictive factor for the type and/or tear of a contralateral DLM. The combination of contralateral DLM and meniscal tear should be evaluated carefully using MRI if the characteristic X-ray findings were present in symptomatic DLM patients.

Disclosure of interest

The authors declare that they have no competing interest.

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Contribution of each author

Seong Hwan Kim: writing article, data interpretation.
Chan Il Bae: data collection, data analysis.
Kang-Il Kim: data collection, review and revised the article.
Joong Won Lee: data collection, data analysis.
Sang Hak Lee: study design, review and revised the article.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.otsr.2019.08.007.

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