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Characteristic morphology of the proximal tibiofibular joint in patients with discoid lateral meniscus

Norifumi Suga *, Tomoyuki Nakasa, Masakazu Ishikawa, Atsuo Nakamae, Seiju Hayashi, Masahiro Yoshikawa, Yoshikazu Sumida, Yusuke Tsuyuguchi, Nobuo Adachi

Dept. of Orthop. Surg., University of Hiroshima, 1-2-3, Kasumi, Minami-ku, Hiroshima 734-8551, Hiroshima, Japan

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ABSTRACT

Background: Patients with discoid lateral meniscus (DLM) are prone to meniscal injuries related to its shape and abnormal mobility. The anatomical joint inclination of the proximal tibiofibular joint (PTFJ) can also affect joint movement in knee motion. However, an association between PTFJ morphology and DLM remains unclear. The purpose of this study was to investigate the morphology of the PTFJ on MRI and how this differs between patients with and without DLM.
Materials and methods: Fifty-eight patients with DLM and 58 age-matched controls (normal meniscus) were included in this study. Slices from preoperative MRI sagittal images that clearly showed the PTFJ were used for measurements. The angle between the PTFJ and the perpendicular line of the fibula axis was measured as the inclination angle, and patients were classified as horizontal-type (<20°) or oblique-type (>20°). The inclination angle was also compared among patients with open and closed epiphysis in both groups to assess the effect of age.
Results: Patients in the horizontal-type PTFJ group frequently had DLM. Before epiphyseal closure, most patients had a horizontal-type PTFJ, with or without DLM. However, in older patients with a closed epiphysis, most with a normal meniscus had an oblique-type PTFJ, and those with DLM retained the horizontal-type joint.
Conclusion: The horizontal-type PTFJ was significantly associated with DLM, and patients with DLM tended to retain a horizontal-type PTFJ after epiphyseal closure. In contrast, in patients with a normal meniscus, the PTFJ may change from a horizontal-type to an oblique-type PTFJ in line with bone maturity.

1. Introduction

Discoid lateral meniscus (DLM) is a common anatomical anomaly of the lateral meniscus frequently reported in the literature [1–4]. In patients with DLM, the meniscus has a unique shape, with increased thickness and broad coverage of the tibia. This tissue variation, however, frequently causes abnormal shearing forces, leading to a high frequency of meniscal tears, more than twice that seen in patients with a normal, crescent-shaped meniscus (20.4% vs. 9.9%) [5,6]. Others also report that the knee joint itself may also show abnormalities in patients with DLM, including changes in bone morphology [7,8]. An understanding of these unique anatomical features and the factors to predispose a high frequency of tears in patients with DLM could lead to the development of a therapeutic strategy for these patients.

* Corresponding author at: Department of Orthopaedic Surgery, Graduate School of Biomedical & Health Sciences, Hiroshima University, 1-2-3 Kasumi, Minami-ku, Hiroshima 734-8551, Japan.
E-mail address: norifuma79@yahoo.co.jp. (N. Suga).

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Recently, the proximal tibiofibular joint (PTFJ) has attracted attention as a cause of pain in the lateral aspect of the knee joint [9–15]. The PTFJ is a plane-type joint, involved in flexion and extension of the knee and dorsiflexion of the ankle. Its movement is defined by its different articular morphology—horizontal and oblique—as classified by Ogden [16,17]. The horizontal-type PTFJ easily rotates as compared with the oblique-type PTFJ. Barnett and Napier reported a fibular lateral rotation of three degrees around the tibia during dorsiflexion of the ankle, which is more pronounced in the horizontal-type as compared with the oblique-type [18].

The lateral meniscus is joined to the fibular head by the meniscofibular ligament, which moves the lateral meniscus along with the PTFJ during knee and ankle motion. Bozkurt et al. [19] showed the meniscofibular ligament to be thicker in horizontal-type PTFJ than in oblique-type PTFJ. The smaller rotation of the fibula in the oblique-type PTFJ means that the meniscofibular ligament is not loaded, whereas, in the horizontal-type, the larger rotation of the fibula leads to loading of the meniscofibular ligament. This additional loading means that the meniscofibular ligament needs to be stronger to withstand the forces acting on it. Thus, the movement of the meniscus in DLM is likely to be different from that of a normal crescent-shaped meniscus.

From these lines of evidence, we hypothesized that the posterior traction acting on the meniscus via the meniscofibular ligament may therefore depend on the PTFJ inclination. In addition, the abnormal movement associated with the anatomical difference of the PTFJ and its effect on the meniscofibular ligament in patients with DLM could be the reason for the increased frequency of tears and, perhaps, may also influence the postoperative results in these patients. The purpose of this study was to evaluate the differences in joint morphology of the PTFJ between patients with and without DLM using magnetic resonance imaging (MRI).

2. Materials and methods

2.1. Patients

Patients who underwent arthroscopic surgery for DLM between January 2008 and December 2016 were included in this study. DLM was diagnosed based on symptomatology and the findings on MRI. All patients with DLM had a pain at lateral joint line but no pain at PTFJ. This retrospective series included 34 males and 24 females, aged seven to 60 years (mean age, 18.2 years). A group of aged-matched control patients without DLM, who underwent anterior cruciate ligament reconstruction or other surgeries (e.g., meniscectomy) at the same time, were included in this study. The control group comprised 30 males and 28 females, aged 11 to 59 years (mean age, 18.5 years). Patients who presented with comorbid systemic diseases, such as rheumatoid arthritis or osteoarthritis, or who had history of knee joint surgery, were excluded from this study. All patients underwent MRI for the knee joint before surgery under conditions of equivalence in the same institution.

2.2. Evaluation

MRI scans were performed using a Signa 1.5-T device or a Signa HDxt 3.0-T device (GE Yokogawa Medical Systems Ltd.) with a wraparound surface coil designed for the knee. The knee was positioned in 0° of extension and rotation. Proton density spin echo (SE) and T2-weighted SE images were collected. The conditions for the T2-weighted images were as follows: repetition time,

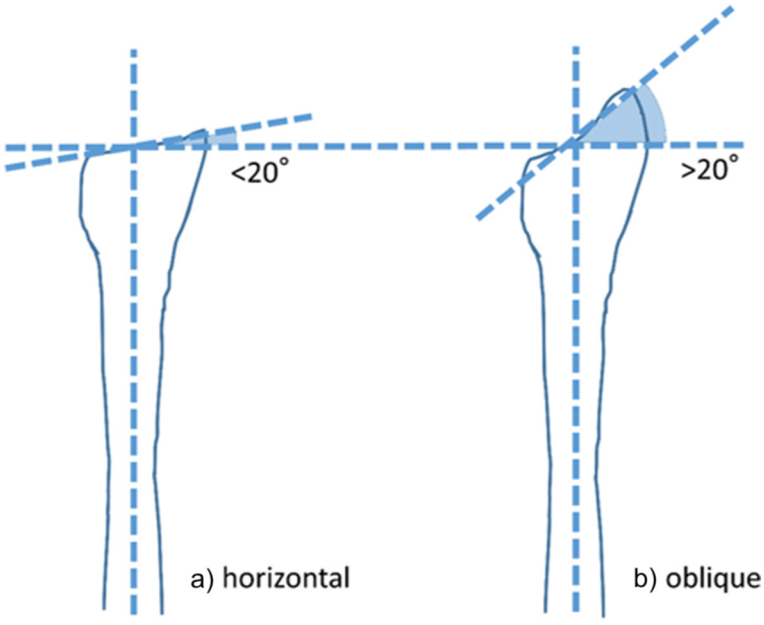

Figure 1. Classification of the proximal tibiofibular joint (PTFJ). The angle between the PTFJ and the perpendicular line of the fibula axis is measured and defined as the inclination angle. Patients are then classified based on a threshold of 20°. a) Horizontal-type (<20°) and b) oblique-type (>20°).

2600 ms; echo time, 98 ms; and section thickness, 4.0 mm. For proton-weighted images, the conditions were as follows: repetition time, 2000 ms; echo time, 20 ms; and section thickness, 4.0 mm.

Sagittal images were obtained, and the slices that most clearly showed the articular surface of the PTFJ were used for evaluation. Sagittal plane was defined perpendicular to the transepicondylar axis. In this series, there was no case obviously out of this plane. The inclination of the PTFJ was evaluated, and the shape of it was classified according to Ogden [16]. The angle between the joint line of PTFJ and the perpendicular line of the fibula axis was measured, and classified as horizontal-type (<20°) or oblique-type (>20°) according to the previous report, which has been widely used for the classification of the PTFJ [16,17,20] (Figures 1, 2).

Finally, an association was determined between the persistence of the epiphysis on MRI and PTFJ type. Patients with DLM were divided into groups by age: children before epiphyseal line closure; teens after epiphyseal line closure; and then adults grouped in 10-year clusters. PTFJ was classified in each group. The number in the control group was increased to 150 subjects to examine the PTFJ type in patients with a normal meniscus and how this was affected by the epiphyseal line.

2.3. Statistical analysis

Staycel statistical software was employed for the statistical analysis. The descriptive data are reported as counts and percentages; patient-reported outcome data are reported as mean ± SD, median, and range. If the data were not normally distributed, the results were presented as the median. The Mann–Whitney *U* test and chi-square test were applied in pairwise comparisons. Two orthopedic surgeons (NS and MK) performed measurements in a randomized order, twice by each rater, with at least 30-day duration between the measurements. Observers selected the image which the articular surface of the PTFJ was most clearly showed from the whole series and measured the inclination angle. Intra- and interobserver reliabilities were analyzed using intraclass correlation coefficients (ICCs). Statistical significance was defined as a 95% confidence interval (CI) for hazard ratios not including 1.0, and the alpha was set to 0.05.

3. Result

In sagittal sections, the inclination angle was 14.7° ± 5.9° for patients in the DLM group and 22.5° ± 9.2° for the control group ($P < 0.05$; Figure 2). Among patients in the DLM group, 43 (74%) patients were classified as having horizontal-type PTFJ and 15 (26%) patients as oblique-type. Within the control group, 22 (38%) patients were classified as having horizontal-type PTFJ and 36 (62%) as oblique-type. The frequency of patients with a horizontal-type PTFJ was significantly higher in the DLM group than in the control group ($P < 0.05$; Table 1).

Among the 58 DLM cases, the epiphyseal line had not closed in 21 (36%) patients (16 horizontal types and five oblique types) and had closed in 37 (64%) patients (27 horizontal types and 10 oblique types). There was no significant association between PTFJ frequency and the presence or absence of the epiphyseal line (Table 2). Also, there is 26 cases (45%) had a tear, but the significant correlation was absent between the type of the PTFJ.

We next divided patients in the DLM and control groups by age, grouping children before epiphyseal line closure, and all other patients after epiphyseal line closure into 10-year age clusters. In patients with DLM, a horizontal-type PTFJ was more frequent than an

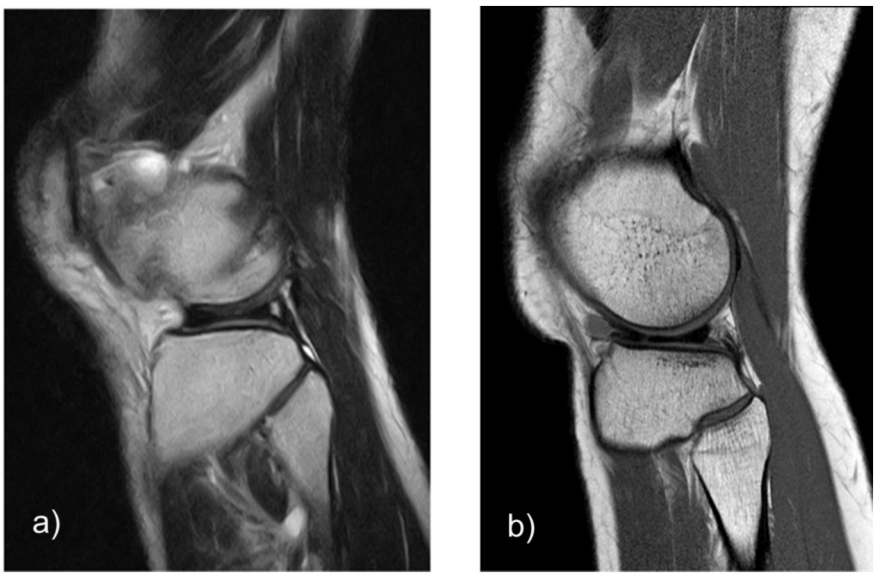

Figure 2. Classification of the PTFJ. a) Oblique-type proximal tibiofibular joint (PTFJ). b) Horizontal-type PTFJ.

Table 1
Classification of the proximal tibiofibular joint (PTFJ) in patients.

	Control	DLM
Inclination angle of PTFJ	22.5 ± 9.2°	14.7 ± 5.9°
Horizontal-type (number)	22	43*
Oblique-type (number)	36*	15

DLM, discoid lateral meniscus.
* $P < 0.05$.

oblique-type PTFJ in all age groups, with no significant difference between patients with closed or unclosed epiphyseal lines. In the control group, among 43 patients with an unclosed epiphyseal line, 32 (74%) patients had a horizontal-type PTFJ, and 11 (26%) patients were oblique-type ($P < 0.05$). However, after epiphyseal line closure, the oblique-type was observed in 75 of 105 patients and was observed more frequently in all age clusters ($P < 0.05$). Overall, we show that horizontal-type PTFJ was found more often before epiphyseal line closure in both DLM and control patients; however, after epiphyseal line closure, the oblique-type PTFJ was more common in patients with a normal meniscus, and a horizontal-type in patients with DLM (Figure 3).

Intra- and interobserver reliability in measuring the inclination angle was analyzed. Intraobserver ICCs for DLM and control were excellent (0.99; 95% CI, 0.98–0.99, 0.99; 95% CI, 0.995–0.997, respectively), and interobserver ICCs for DLM and control were excellent (0.94; 95% CI, 0.89–0.97, 0.83; 95% CI, 0.66–0.91, respectively).

4. Discussion

In 1974, Ogden investigated the tibiofibular joint in 84 specimens (50 cadaveric knees, four fresh autopsies, and 30 dried bone tibiofibular units) and 200 roentgenograms, and defined a simple classification for the PTFJ [16], which is still widely used within the literature. However, whether there is an association between the shape of the PTFJ and the presence of DLM was not clear and, to the best of our knowledge, this is the first report to describe an association between PTFJ and DLM.

Numerous studies have outlined the morphological characteristics of DLM [7,21–25] and, compared with a normal meniscus, patients with DLM have a higher frequency of meniscal tears [5,6]. In this study, we showed that most patients with DLM have a horizontal-type PTFJ. During flexion and extension of the knee, the PTFJ is subjected to an anterior–posterior force: in flexion, the fibula is pulled anteriorly and moves about one centimeter, whereas, in extension, the joint is subjected to a posterior force [16]. In addition, the fibula rotates three degrees externally during ankle dorsiflexion [17]. Although three degrees rotation angle of fibula seems to be trivial, three degrees rotation by dorsiflexion of ankle combined with anterior–posterior force by the extension and flexion of the knee may generate critical force for DLM. Actually, in one of the earlier studies, it was observed that there is an increased amount of rotation of the fibula at the PTFJ in horizontal variants than the oblique variants [19]. Furthermore, the thicker meniscofibular ligament in those with a horizontal-type PTFJ is thought to cause a larger posterior traction force. This means that the fibula rotation increases in patients with DLM, and the meniscal retrodisplacement and higher traction force may be responsible for the high frequency of tearing in these patients.

Horizontal-type PTFJ was more frequent in patients with DLM across all age clusters with or without fusion of the epiphyseal line, whereas the oblique-type PTFJ appeared more frequently in patients with a normal meniscus after the epiphyseal line had closed. There are two possible reasons. The knee with DLM may have frequently the horizontal type of the PTFJ from the development stage. Conceivably, all knees may have originally the horizontal type of the PTFJ, but a horizontal type of the PTFJ with normal meniscus may change to the oblique type of the PTFJ in growth because of the smaller articular range and the reduced load as compared with that in patients with DLM. It is plausible that the horizontal-type of the PTFJ may remain in patients with DLM to compensate for the decrease in proper meniscal behavior. Longitudinal analysis with the observation of the change of the PTFJ type in growth should be needed. A large mobility in patients with horizontal-type of the PTFJ is reported as a cause of lateral knee pain [15,26]. In patients with DLM, there is likely to be a higher load to the PTFJ to supplement the limited DLM behavior, and this may contribute to more pain in the knee.

Table 2
Classification of PTFJ before and after epiphyseal line closure.

		Epiphyseal line		Generation		
		Open	Close	20 years	30 years	40 years
Control	Oblique (%, (number/total))	25.6(11/43)	67.9(19/28)	59.4(19/32)	73.9(17/23)	83.3(20/24)
	Horizontal (%, (number/total))	74.4(32/43)	32.1(9/28)	40.6(13/32)	26.1(6/23)	16.7(4/24)
DLM	Oblique (%, (number/total))	23.8(5/21)	33.3(6/18)	25.0(2/8)	40.0(2/5)	0.0(0/6)
	Horizontal (%, (number/total))	76.2(16/21)	66.6(12/18)	75.0(6/8)	60.0(3/5)	100.0(6/6)

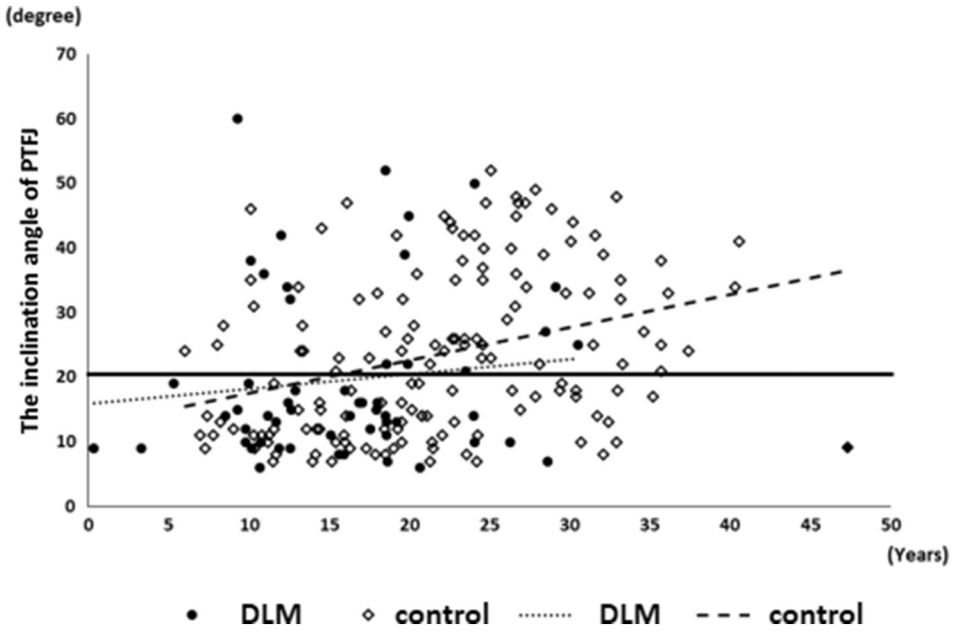

Figure 3. Relationship between the inclination angle and age. DLM; discoid lateral meniscus.

There are some limitations in this study. First, the number of subjects is small. Moreover, DLM with no symptoms was not included in this study. The difference of the inclination angle at PTFJ in DLM between with and without symptoms will help to understand the pathomechanism of symptomatic DLM. In addition, although we revealed that patients with DLM were more likely to have a horizontal-type PTFJ, the actual influence and the mechanism that this difference has in patients with DLM including symptoms is unclear. Finally, we did not elucidate whether the shape of the PTFJ change or not, and when DLM was formed. Further examination and cadaveric study will be necessary to elucidate a more detailed mechanism in the relationship between the PTFJ type and DLM and to design a relevant clinical treatment strategy. Furthermore, longitudinal growth studies would help to confirm this morphological change associated with epiphyseal closure.

5. Conclusion

Among DLM cases, a significantly higher proportion of patients had horizontal-type PTFJ. We suspect that this type of PTFJ may affect the frequency of the meniscus tear in these patients.

Declaration of interest

None.

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