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Original Article

Tibial eminence width can predict the presence of complete discoid lateral meniscus: A preliminary study

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ABSTRACT

Background: To compare the plain knee radiograph finding of tibial eminence width between knees with complete discoid lateral meniscus, incomplete discoid lateral meniscus, and normal lateral meniscus.
Materials and methods: The study included 27 knees with discoid lateral meniscus, including 13 knees with complete discoid lateral meniscus and 14 knees with incomplete discoid lateral meniscus. A control group of 14 knees with normal lateral meniscus was also included. Tibial eminence width and the lateral slope angle of the medial tibial eminence were assessed using plain frontal knee radiographs. Individual differences in knee size were corrected by dividing tibial eminence width by tibial width to obtain the tibial eminence width percentage.
Results: Mean tibial eminence width and tibial eminence width percentage in the complete discoid lateral meniscus group was significant larger than other groups. Mean lateral slope angle in the complete discoid lateral meniscus group was significantly smaller than other groups. A tibial eminence width cut-off of 13.9 mm showed a sensitivity and specificity of 100% and 83%, respectively. A tibial eminence width percentage cut-off of 18.8% showed a sensitivity and specificity of 100% and 90%, respectively. A lateral slope angle cut-off of 27.1° showed a sensitivity and specificity of 71% and 83%, respectively.
Conclusion: There were clear differences in tibial eminence width, tibial eminence width percentage, and lateral slope angle between the complete discoid lateral meniscus group and the other groups. The plain radiographic parameters identified by this study could be useful for complete discoid lateral meniscus screening.
Study design: Clinical.

1. Introduction

Compared to a normal lateral meniscus, a discoid lateral meniscus (DLM) is thicker, disc-shaped, and covers not just the periphery but also extends towards the middle of the tibia. The reported prevalence of DLM varies widely, from 0.7 to 16.6% [1–4]. DLM is more prevalent in Asian populations, including Japanese people. Compared to a normal lateral meniscus, DLM is reported to be more prone to tears [5,6]. A torn DLM causes knee pain due to catching or locking of the knee and may result in decreased range of motion. A torn DLM also increases the contact pressure on the articular surface, which gives rise to knee osteoarthritis [7,8]. DLM is classified as complete DLM (CDLM) and incomplete DLM (ICDLM), where a CDLM is thicker than an ICDLM and thus more prone to tears and exacerbation of tears [9,10]. Lateral meniscus tears become more difficult to treat as they increase in size, so DLM must be diagnosed early before this occurs [11].

Various methods can be used to diagnose DLM, including plain radiography, ultrasonography, and magnetic resonance imaging (MRI) [9,12]. MRI displays the shape of the lateral meniscus clearly, but it is expensive and not available at all hospitals. Plain radiography was the technique initially used to diagnose symptomatic DLM. Previous studies have reported significant differences in bone morphology between plain frontal knee radiographs of DLM and normal lateral meniscus knees [13]. In previous studies, compared to normal knees, the plain radiographs of DLM knees have a wider lateral joint space, hypoplasia of the lateral femoral condyle, hypoplasia of the lateral tibial eminence, and high fibular head [14].

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There has also been recent report of a significant difference in the condylar cut-off sign, which is a plain radiographic finding, between CDLM knees and normal knees [15]. However, the technique used in this report is not particularly convenient as the imaging method differs from normal frontal knee radiography.

Many cases of DLM have a large distance between tibial spines on frontal knee radiography. However, no study has yet investigated the relationship of the distance between tibial spines and CDLM. We propose the hypothesis that the distance between tibial eminence peaks on plain radiographs is larger in CDLM knees than in normal knees. The purpose of this study is to elucidate the morphological differences between DLM knees and normal lateral meniscus knees in plain radiographs.

2. Materials and methods

2.1. Specimen preparation

Between January 2003 and December 2015, 116 knees were diagnosed with DLM at our hospital by MRI. All methods for this study were approved by the institutional review board at our institution, and the requirement for informed consent was waived due to the retrospective nature of the study design. Of these, 27 knees with DLM were investigated in this study after excluding patients aged 15 years or under without bone maturation, patients aged 45 years or older with morphological bone changes from causes such as knee osteoarthritis, and patients with blurred MRI images. The three groups compared in this study were a normal lateral meniscus group and DLM knees divided into a CDLM group and an ICDLM group. Of the 27 DLM knees, there were 13 CDLM knees and 14 ICDLM knees (Table 1). The normal group consisted of 14 knees with a normal lateral meniscus, which were matched to the other groups by age and sex. The CDLM group consisted of 6 knees from 6 males patients and 7 knees from 6 female patients; the mean patient age of the CDLM group was 25.9 years. The ICDLM group consisted of 7 knees from 7 male patients and 7 knees from 7 female patients; the mean patient age in the ICDLM group was 28.9 years. The normal knee group consisted of 8 knees from 8 male patients and 6 knees from 6 female patients; the mean patient age in the normal knee group was 20.9 years.

2.2. MRI examination

All MRI examinations were performed with a 3.0T system (MAGNETOM Skyra, Siemens Healthcare). Conventional MRI was performed with axial proton density sequence, sagittal proton density and T2 fat-suppressed sequences, and coronal proton density and T2 sequences. MRI was used to divide DLM knees into CDLM and ICDLM knees. In MRI coronal sections, the minimum width of the lateral meniscus (a) and the tibial articular surface (b) were used to calculated the a/b ratio, where $a/b < 0.2$ was deemed a normal meniscus, $a/b \geq 0.2$ and <0.32 was deemed ICDLM, and $a/b \geq 0.32$ was deemed CDLM [16].

Table 1
Demographics of the complete discoid lateral meniscus, incomplete discoid lateral meniscus, and normal meniscus groups.

	CDLM	ICDLM	Normal meniscus
Number of patients (knees)	12 (13)	14 (14)	14 (14)
Mean age (range)	25.9 (15–40)	28.9 (17–40)	20.9 (15–40)
No. of male/female patients	6/6	7/7	8/6

CDLM, complete discoid lateral meniscus; ICDLM, incomplete discoid lateral meniscus.

2.3. Radiographic evaluation

All patient radiographs were non-weight-bearing and obtained at a distance of 110 cm in the anteroposterior view (Fig. 1). The anteroposterior view was taken with the knee extended in a supine position, the cassette behind the knee, and the central X-ray beam perpendicular to the cassette. To obtain true anteroposterior radiographs of the knee, care was taken to make sure that the patella was pointing anteriorly. We defined that a well-centered anteroposterior radiograph has the patella centered over the femoral condyles and overlap of 50% of the fibula head with the lateral tibial condyle [17]. Each plain radiograph in anteroposterior view was evaluated for the following parameters: tibial width, tibial eminence width (TEW), and percentage of TEW relative to tibial width (TEW percentage). Tibial width was defined as the maximum tibial plateau width. TEW was defined as the distance between the peak of the medial tibial eminence and the lateral tibial eminence (Fig. 2). Individual differences in knee size were corrected by dividing TEW by tibial width to obtain the TEW percentage. The lateral slope angle (LSA) of the medial tibial eminence was also evaluated (Fig. 1). LSA was measured as the angle formed between the tibial articular surface and the lateral slope of the medial tibial spine. All plain radiography measurements were made twice, with a 2-week interval in between, by 2 different orthopedic surgeons, each with at least 7 years of clinical experience.

2.4. Statistical analyses

The mean and standard deviation of each parameter was calculated for each group. A one-way analysis of variance (ANOVA) with the post hoc tests (Tukey–Kramer honest significance test) was used to compare TEW, TEW percentage, and LSA between the CDLM group, ICDLM group, and normal group. Significance was set at $P < 0.05$. Receiver operating characteristic (ROC) curves and the area under the curve (AUC) were used to determine cut-off values for TEW, TEW percentage, and LSA for CDLM screening.

All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). More precisely, EZR is a modified version of R commander designed to add statistical functions frequently used in biostatistics [18].

3. Results

There was no significant difference between the CDLM group, ICDLM group, and normal group in terms of age or sex. Mean TEW was 15.8 ± 3.1 mm in the CDLM group, 12.6 ± 1.8 mm in the ICDLM group, and 12.6 ± 1.2 mm in the normal group (Fig. 3). TEW in the CDLM group was significantly larger than that in the ICDLM and normal groups ($P < 0.05$). There was no significant difference in TEW between the ICDLM and normal groups. Mean TEW percentage was $21.8 \pm 2.7\%$ in the CDLM group, $16.4 \pm 2.3\%$ in the ICDLM group, and $16.7 \pm 1.7\%$ in the normal group (Fig. 4). TEW percentage in the CDLM group was also significantly larger than that in the ICDLM and normal groups ($P < 0.05$). There was no significant difference in TEW percentage between the ICDLM and normal groups. The mean LSA was $23.6 \pm 4.2^\circ$ in the CDLM group, $29.8 \pm 2.8^\circ$ in the ICDLM group, and $28.6 \pm 3.0^\circ$ in the normal group (Fig. 5). The LSA in the CDLM group was significantly smaller than that in the ICDLM and normal groups ($P < 0.05$). There was no clear difference in LSA between the ICDLM group and the normal group.

In this study, diagnostic performance was evaluated by ROC. The cut-off values, sensitivity, and specificity of plain radiographic parameters (TEW, TEW percentage, and LSA) for CDLM diagnosis are

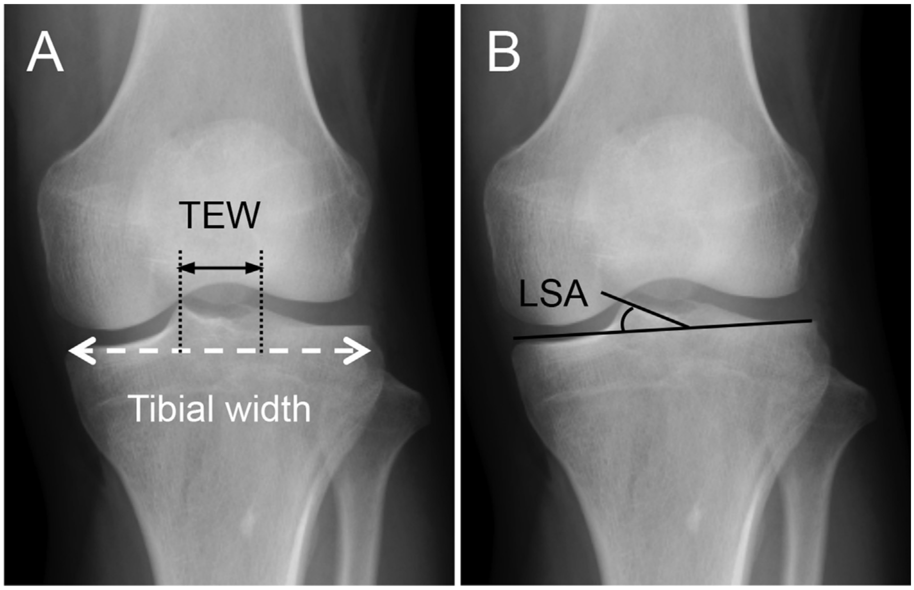

Fig. 1. Knee radiographs of a complete discoid lateral meniscus. (A) Tibial eminence width (TEW, double-headed arrow). Tibial width (dashed double-headed arrow). (B) Lateral slope angle (LSA) of the medial tibial eminence.

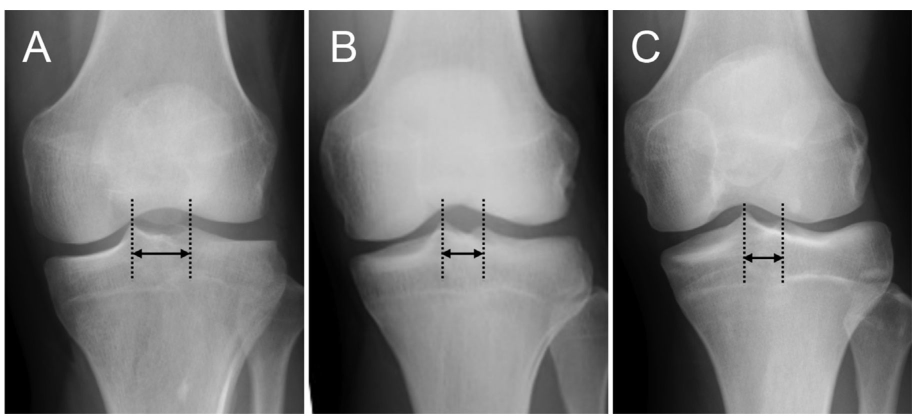

Fig. 2. Radiographic assessments of the tibial eminence width on non-weight-bearing anteroposterior view. (A) Complete discoid lateral meniscus. (B) Incomplete discoid lateral meniscus. (C) Normal knee.

shown in Table 2. When the TEW cut-off was set at 13.9 mm or above in the CDLM and normal groups, CDLM diagnostic sensitivity was 100% and specificity was 83%, respectively (AUC = 0.90). When the TEW percentage cut-off was set at 18.8% or above in the CDLM and normal groups, CDLM diagnostic sensitivity and specificity were both high at 100% and 90%, respectively (AUC = 0.97). When the LSA cut-off was set at 27.1° or smaller, CDLM diagnostic sensitivity and specificity were both high at 71% and 83%, respectively (AUC = 0.83).

Correlation analysis of the prominence ratio calculated based on parameters measured by two independent observers revealed an interclass correlation coefficient of 0.89 and an intraclass correlation coefficient of 0.92. This showed that the prominence ratio measurements were highly reliable, regardless of observer and timing of observation.

4. Discussion

The most important finding of this study is the significant difference in TEW, TEW percentage, and LSA measured on plain frontal knee radiographs of CDLM knees compared to both ICDLM knees and normal lateral meniscus knees. The TEW cut-off resulted in high CDLM diagnostic sensitivity (100%) and specificity (83%), the TEW percentage cut-off resulted in high CDLM diagnostic sensitivity (100%) and specificity (90%) and the LSA cut-off also resulted in high CDLM diagnostic sensitivity (71%) and specificity (83%). Consequently, we deemed that these plain radiographic findings specific to CDLM would be useful as indices in CDLM screening. Furthermore, an advantage of this method is the ability to detect CDLM using normal plain frontal knee radiographs without the need for special radiographic methods or MRI. TEW measurements are also very simple to perform and therefore suitable for screening.

Many reports have shown plain radiographic findings that are specific to CDLM knees. A study that compared plain frontal knee radiographs of 91 DLM knees and 91 normal lateral meniscus knees in children reported that, compared to normal knees, plain frontal knee radiographs of DLM knees differed in having a large lateral joint space, high fibular head, hypoplasia of the lateral tibial eminence, and flattening of the lateral femoral condyle [19]. However, the DLM diagnostic sensitivity and specificity of each of these findings ranged from 51.1 to 78.0% and 52.2 to 72.5%,

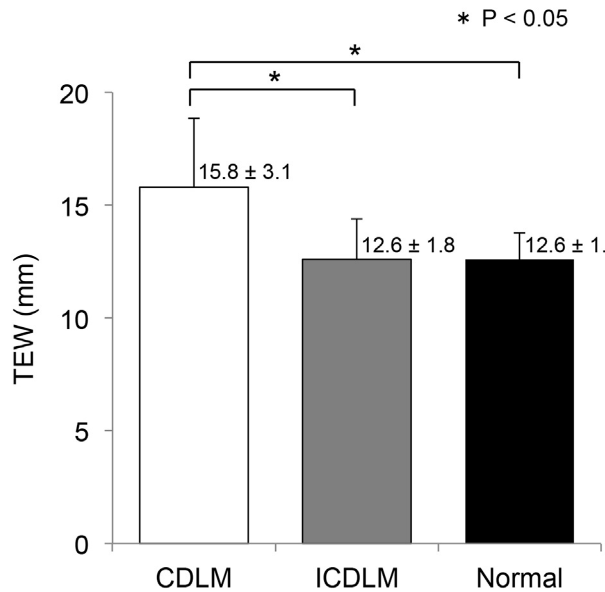

Fig. 3. Comparison of tibial eminence width (TEW) on plain radiograph. CDLM, complete discoid lateral meniscus. ICDLM, incomplete discoid lateral meniscus.

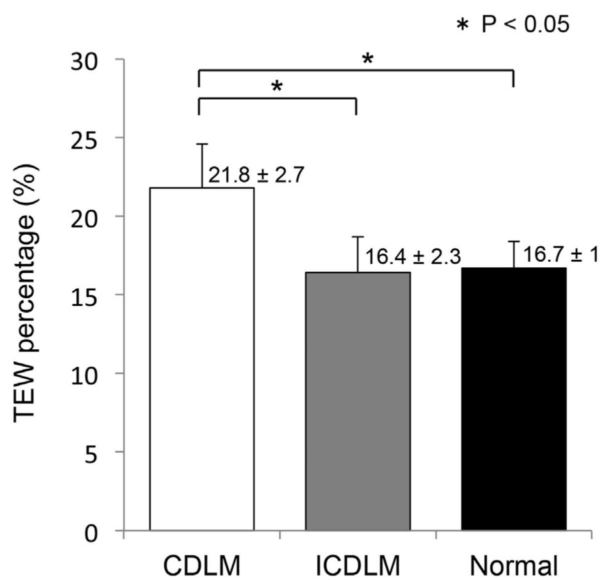

Fig. 4. Comparison of tibial eminence width (TEW) percentage on plain radiograph. CDLM, complete discoid lateral meniscus. ICDLM, incomplete discoid lateral meniscus.

respectively, lower than the CDLM diagnostic sensitivity and specificity of TEW, TEW percentage, and LSA observed in the present study. Another study also stated that the condylar cut-off sign, which is a plain radiographic finding, is useful for CDLM screening [13]. This previous study used plain radiographs in tunnel view, which limits the versatility of this technique, and reported CDLM diagnostic sensitivity and specificity of 79.4% and 73%, respectively. A possible reason for the difference in sensitivity and specificity observed in our study compared to previous reports is that previous studies did not divide DLM into CDLM and ICDLM before analysis. CDLM and ICDLM are clearly different morphologically, thus grouping ICDLM and CDLM knee measurements in a single DLM group before analysis would probably reduce the significant difference, sensitivity, and specificity for each radiographic parameter. Few studies have investigated plain radiographic findings in groups

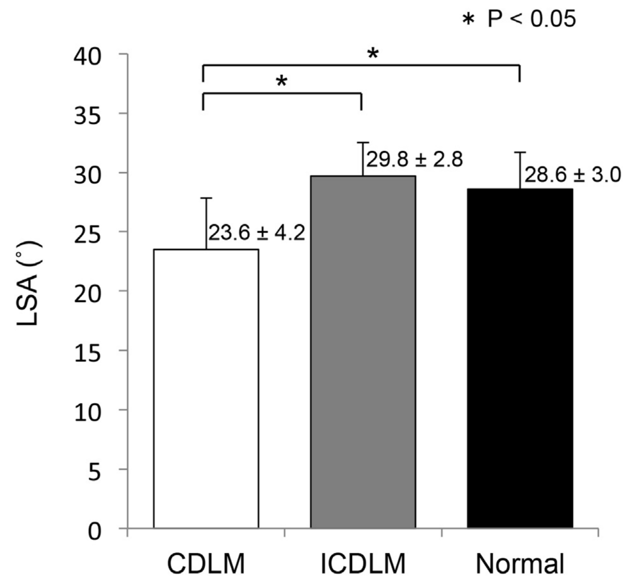

Fig. 5. Comparison of lateral slope angle (LSA) on plain radiograph. CDLM, complete discoid lateral meniscus. ICDLM, incomplete discoid lateral meniscus.

Table 2
Sensitivity and specificity in the diagnosis of the complete discoid lateral meniscus.

	Cut-off value	Sensitivity (%)	Specificity (%)
TEW (mm)	13.9	100	83
TEW percentage (%)	18.8	100	90
LSA (°)	27.1	71	83

TEW, tibial eminence width; TEW percentage = 100 × TEW/tibial width; LSA, lateral slope angle.

of CDLM, ICDLM, and normal lateral meniscus knees. Song et al. reported a relatively high sensitivity and specificity when fibular height, lateral joint space, lateral tibial eminence height, and condylar cut-off sign were investigated after dividing DLM into CDLM and ICDLM [20]. However, Song et al. did not investigate the TEW parameter proposed by the present study. In the present analysis, we compared TEW—a new plain radiographic indicator of CDLM—between CDLM, ICDLM, and normal lateral meniscus knee groups, and found that clinically problematic CDLM was more likely to be detected by comparing TEW. In addition, we found that TEW, TEW percentage, and LSA are radiographic parameters characteristic to CDLM that can be examined on plain frontal knee radiographs, making their measurement easy and therefore very convenient.

In our study, we found that the CDLM group have wide TEW percentage and hypoplasia of LSA of medial tibial eminence on plain radiographs. We speculate that the wide TEW percentage value was a result of hypoplasia of the lateral tibial eminence adjacent to the thick anterior portion of CDLM. On the other hand, we predicted that CDLM knees exhibit a wide anterior medial root ligament compared with knees with a normal meniscus. The tibial attachment of the anterior cruciate ligament (ACL) is extruded inward by the wide anterior medial root ligament of CDLM, because of which the width of the tibial attachment of ACL is increased. This is probably why LSA of the medial tibial eminence was smaller for CDLM knees than for knees with a normal meniscus.

This study has a number of limitations. First, all study participants were Japanese. Despite this, we still consider the results of this study to be useful since DLM is highly prevalent in Asia, where the disease is commonly encountered. Second, patients 15 years of age or younger were excluded from the study. The reason for this exclusion is that bone maturation has yet to occur in children aged 15 years or younger, thus the tibial eminence is not fully formed and evaluation is difficult. Based on previous reports, the plain radiographic parameters that differ significantly between CDLM and normal lateral meniscus knees in young patients and that can be used to detect CDLM are lateral tibial height, lateral joint space, fibular head height, and obliquity of the lateral tibial plateau [13,19]. Of these, the most useful is fibular head height, which has been demonstrated to yield a sensitivity and specificity of 78.0% and 60.9%, respectively. Nevertheless, fibular head height cannot be described as having a high detection rate for CDLM, and in young patients plain radiographic parameters characteristic of CDLM must be evaluated together as a whole. Third, we included a small number of patients. The results of this study will need to be confirmed by examining a larger sample group.

5. Conclusions

This study shows that a large tibial eminence width and a low lateral slope angle of the medial tibial eminence are plain radiographic findings characteristic of CDLM. In addition, because we observed a significant difference in TEW, TEW percentage, and LSA between the CDLM group and the ICDLM and normal groups, these plain radiographic findings could be useful for CDLM screening.

Conflicts of interest

None.

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