

Evaluation of the morphological variations of the meniscus: a cadaver study

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Abstract

Purpose The purpose of this study was to reveal the prevalence of the subtypes of the meniscus using human cadaver knees.

Methods Four hundred and thirty-seven cadaveric knees in 219 subjects (formalin fixed, Japanese population) with a median age of 83 years (54–97) were included in this study. All soft tissues surrounding the knee, excluding the meniscus, were resected, and macroscopic assessment of the meniscus was performed. Meniscus subtypes were classified as: (1) normal meniscus, (2) complete discoid, (3) incomplete discoid, (4) ring-shaped, and (5) double-layered.

Results All subtypes of the meniscus were observed in the lateral meniscus. Complete discoid lateral meniscus was observed in 27 knees (6.2 %), incomplete discoid lateral meniscus was observed in 139 knees (31.8 %), ring-

shaped lateral meniscus was observed in 4 knees (0.9 %), and double-layered meniscus was observed in 2 knees (0.5 %).

Conclusion This study reports the accurate prevalence of ring-shaped and double-layered meniscus. None of the subtypes were detected in the medial meniscus in this study. For clinical relevance, the results of this study can be useful in assisting the diagnosis of meniscus tear in clinical situations.

Keywords Anatomy · Meniscus · Morphology · Subtypes · Discoid

Abbreviations

ACL Anterior cruciate ligament
LM Lateral meniscus
MM Medial meniscus

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Introduction

The most common anatomical subtype of the meniscus is discoid meniscus [14, 21, 23]. Watanabe et al. [21] classified discoid lateral meniscus into three types: complete discoid lateral meniscus (CDLM), incomplete discoid lateral meniscus (ICDLM), and Wrisberg ligament type. However, the Wrisberg ligament type was not observed in his study. It has been reported that discoid lateral meniscus can be a cause of meniscus tear due to low vascularity and abnormal stress distribution [12, 14, 23]. Although the common treatment of meniscal tear for discoid lateral meniscus is surgery, the prevalence of CDLM or ICDLM has not been well investigated. A higher frequency of discoid meniscus in Asian

populations compared to European countries or the United States has been reported [23]. To the best of our knowledge, only Kato et al. [12] have reported on the prevalence of CDLM and ICDLM using cadaveric knees. However, they evaluated only discoid lateral meniscus; medial meniscus morphology and other subtypes of the meniscus were not evaluated.

In some case reports, discoid medial meniscus [1, 6, 7, 18], ring-shaped meniscus [2, 3, 8, 13, 15], and double-layered meniscus [11, 17, 19, 20] have been reported as extremely rare cases. However, the accurate prevalence of these subtypes is still unknown.

The purpose of this study was to reveal the prevalence of meniscal subtypes using cadaveric knees. The hypothesis was that a clinically useful characteristic prevalence of meniscal subtypes would be revealed.

Materials and methods

Four hundred and thirty-seven (437) cadaveric knees from 219 subjects (formalin fixed, Japanese population) with a median age of 83 years (54–97) were included in this study. All soft tissues surrounding the knees, excluding the meniscus, were resected. Knees were deeply flexed, and macroscopic assessment of the medial and lateral meniscus was performed. When necessary, the anterior cruciate ligament or posterior cruciate ligament was resected to expose the meniscus. Meniscus subtypes were classified as, (1) normal meniscus, (2) complete discoid meniscus, (3) incomplete discoid meniscus, (4) ring-shaped meniscus, and (5) double-layered meniscus. Following Watanabe et al.'s [21] classification, complete and incomplete discoids were differentiated. Although Watanabe did not describe the accurate coverage of articular surface with meniscus in complete and incomplete discoids, complete disc-shaped meniscus was regarded as complete discoid, and when approximately half or more articular surface was covered with meniscus, it was regarded as incomplete meniscus in this study. In this study, when the meniscus had complete circular shape, and the edge was perfectly connected with surround soft tissue, it was regarded as ring-shaped meniscus. Suzuki et al. [17] firstly described about double-layered meniscus. Following his description, when the upper additional meniscus was connected at the posterior horn and middle segments of the lower meniscus, it was regarded as double-layered meniscus in this study. Excluded criteria of this study were severe meniscal tear which could not evaluate the morphological characteristics, visible surgical treatment such as arthroplasty or ligament reconstruction. All evaluation of meniscus subtypes was performed with two well-trained orthopaedic surgeons (R. K and K. Y) and confirmed by senior surgeon (M. O).

Statistical analysis

Data are presented as mean \pm standard deviations. Pearson's χ^2 test was performed to reveal the correlation between gender and the prevalence of meniscus subtypes. Collected data were analysed using SPSS for Windows, Version 19.0 (SPSS Inc., Chicago, IL, USA) software. Values were considered significantly different at $p < 0.05$.

Results

No severe meniscus tear, which could not be evaluated its anatomical morphology, was observed in this study.

None of the subtypes were detected in the medial meniscus. All medial menisci were classified as normal (Table 1).

In the lateral meniscus subtype classification, 265 knees (60.6 %) were classified as Normal. 27 knees (6.2 %) were classified as CDLM. 9 subjects (18 knees) had bilateral CDLM. 139 knees (31.8 %) were classified as ICDLM (Fig. 1). 55 subjects (110 knees) had bilateral ICDLM. Ring-shaped meniscus was observed in only 4 knees (0.9 %) (Fig. 2). All ring-shaped menisci were observed in male knees. One male had bilateral ring-shaped meniscus, and 2 other males had it in their one-side knee. Double-layered meniscus was extremely rare, observed in only 2 knees of 2 females (0.5 %) (Fig. 3; Table 1). Other subtypes of the lateral meniscus were not observed.

The prevalence of meniscus subtypes was significantly different between male and female knees ($p = 0.041$) (Table 2). All cases of ring-shaped meniscus were found in male knees, and all cases of double-layered meniscus were found in female knees. The prevalence of ICDLM was relatively higher in female knees than male knees.

Table 1 The prevalence of the subtypes of the meniscus

| | Medial meniscus | Lateral meniscus |
|--------------------|-----------------|------------------|
| Normal | 437 (100 %) | 265 (60.6 %) |
| Complete discoid | 0 | 27 (6.2 %) |
| Incomplete discoid | 0 | 135 (31.8 %) |
| Ring-shaped | 0 | 4 (0.9 %) |
| Double-layered | 0 | 2 (0.5 %) |
| Other | 0 | 0 |
| Total | 437 | 437 |

None of the subtypes were detected in the medial meniscus. The total prevalence of discoid lateral meniscus was more than 30 %. The prevalence of ring-shaped and double-layered meniscus was extremely low

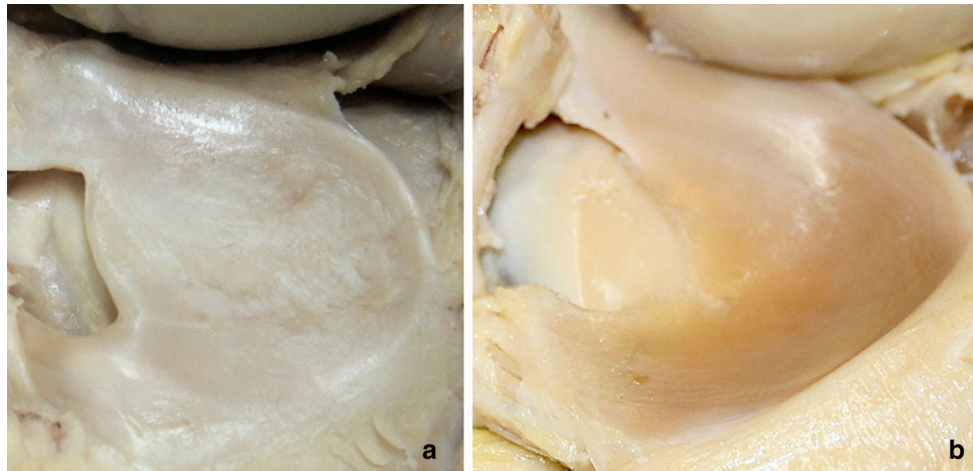


Fig. 1 Complete discoid lateral meniscus (CDLM) and incomplete discoid lateral meniscus (ICDLM). **a** CDLM was observed in 27 knees (6.2 %). **b** ICDLM was found in 139 knees (31.8 %)

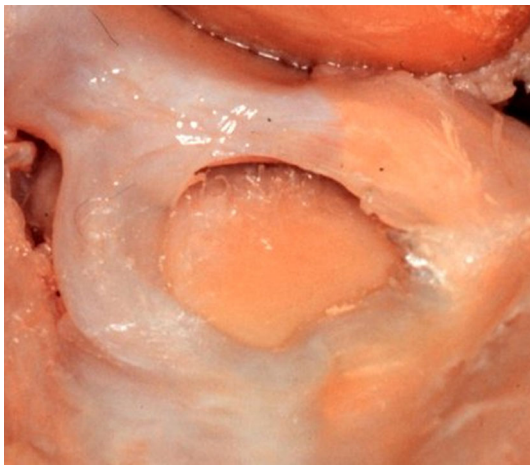


Fig. 2 Ring-shaped meniscus. Ring-shaped meniscus was observed in only 4 knees (0.9 %). All ring-shaped menisci were observed in the lateral meniscus of male subjects



Fig. 3 Double-layered meniscus. Double-layered meniscus was extremely rare, occurring in 2 female knees (0.5 %)

Discussion

The most important finding of this study was the revelation of the accurate prevalence of CDLM and ICDLM, and the extremely low prevalence of ring-shaped meniscus and double-layered meniscus, using a relatively large sample size of cadaveric knees. None of the subtypes were detected in the medial meniscus in this study. A significant difference in gender on the prevalence of meniscus subtypes was observed. All cases of ring-shaped meniscus were found in male knees, and all cases of double-layered meniscus were found in female knees. The prevalence of ICDLM was relatively higher in female knees (36.3 %) than male knees (28 %).

Clinically, the common treatment of meniscal tear for CDLM and ICDLM is surgery [12, 14, 23]. However,

determining the actual prevalence of discoid meniscus is difficult in clinical situations due to the high rate of asymptomatic patients. The clinically reported prevalence of discoid lateral meniscus ranges from 0.4 to 17 % [4, 9, 10, 12, 14, 16, 23]. Some authors have tried to reveal a more accurate prevalence of discoid meniscus using human cadaver knees. Kaplan was the first to report on discoid meniscus using cadaver knees [10]. However, his study did not report the prevalence. Cassells [5] reported that 15 discoid lateral menisci were found in 300 aged cadaver

Table 2 Gender difference and the prevalence of lateral meniscus subtypes

| | Female | Male |
|----------------|--------------|--------------|
| Normal | 112 (55.7 %) | 153 (64.8 %) |
| CDLM | 14 (7 %) | 13 (5.5 %) |
| ICDLM | 73 (36.3 %) | 66 (28 %) |
| Ring-shaped | 0 | 4 (1.7 %) |
| Double-layered | 2 (1 %) | 0 |
| Total | 201 | 236 |

Statistical analysis showed a significant difference in gender on the prevalence of lateral meniscus subtypes. Ring-shaped meniscus was observed only in male knees, and double-layered meniscus was observed only in female knees. The prevalence of ICDLM and CDLM tended to be higher in female subjects

knees. However, their study did not differentiate between CDLM and ICDLM. Kato et al. [12] conducted a cadaveric study using the same classification as this study. The reported prevalence of CDLM and ICDLM in their study was 3.6 and 29.6 %, respectively. They also concluded that the incidence of meniscal tear in ICDLM was significantly higher than that in normal menisci. Their results are similar to those of this study. In this study, the total prevalence of discoid lateral meniscus was more than 30 %. Considering the difference between clinical and cadaveric reports on the prevalence of discoid lateral meniscus, it is possible that over half of all subjects with discoid lateral meniscus do not exhibit clinical symptoms.

In contrast to the high prevalence of lateral discoid meniscus, previous studies have shown the prevalence of medial discoid meniscus to be low (0.06–1.5 %) [1, 6, 7, 18]. Recently, Chen et al. [6] reported 13 cases of discoid medial meniscus. In their study, a significantly higher prevalence of discoid medial meniscus was observed in male subjects. In this study, none of the subtypes were detected in the medial meniscus. In a larger sample size, these subtypes might be found.

Watson–Jones [22] first reported on ring-shaped meniscus in 1930. Since then, only few cases of ring-shaped meniscus have been reported [2, 3, 8, 13, 15]. Most of them occurred in the lateral meniscus, and the actual prevalence is still unknown. In this study, 4 out of 437 knees had ring-shaped lateral menisci, a low prevalence of 0.9 %. Considering the firm structure of ring meniscus, most of cases exhibit no clinical symptoms. This may account for the low prevalence of ring-shaped meniscus injury reported in clinical studies. Ring-shaped meniscus should be differentiated clearly with the bucket-handle tear of meniscus [15]. In this study, as shown in Fig. 2, the edge of ring-shaped meniscus was firmly connected with surrounded soft tissue, and the morphological finding was accurately different with bucket-handle tear.

As with ring-shaped meniscus, double-layered meniscus is also rare. In 1991, Suzuki et al. [17] first reported on this subtype. According to previous reports, double-layered meniscus is likely to occur in the lateral meniscus of male subjects [11, 17, 19, 20]. In this study, only 2 of 437 knees exhibited double-layered meniscus. They were found in the knees of female subjects, and the prevalence was <0.5 %. To the best of our knowledge, this is the first report to reveal the actual prevalence of ring-shaped and double-layered meniscus. Clinically, double-layered meniscus is tended to be misdiagnosed as horizontal tear of meniscus [19]. However, in this study, as original description of Suzuki et al. [17], additional layer of meniscus was clearly identified.

A significant difference in gender on the prevalence of lateral meniscus subtypes was observed in this study. Ring-shaped meniscus was found only in male knees, and double-layered meniscus was found only in female knees. Moreover, the prevalence of CDLM and ICDLM tended to be higher in female subjects.

The limitations of this study were (1) only knees of elderly subjects were included in this study. (2) Only Japanese subjects were included in this study. Knee morphology might be influenced by differences in ethnicity, and therefore, knees of other ethnic groups should be evaluated in future studies.

For clinical relevance, this study reveals the prevalence of meniscus subtypes. In particular, the accurate prevalence of the extremely rare ring-shaped meniscus and double-layered meniscus is reported for the first time. The results of this study can be useful in assisting the diagnosis of meniscus tear in clinical situations.

Conclusion

In conclusion, this study revealed the prevalence of subtypes of the meniscus using cadaver knees. The prevalence of total discoid lateral meniscus (CDLM and ICDLM) was more than 30 %. However, the prevalence of ring-shaped and double-layered meniscus was extremely low. No subtypes were detected in the medial meniscus.

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