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ORIGINAL ARTICLE

Yuki Kato · Midori Oshida · Shin Aizawa · Akiyoshi Saito
Junnosuke Ryu

Discoid lateral menisci in Japanese cadaver knees

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Abstract We undertook a descriptive, observational study to determine the prevalence of the discoid lateral menisci. The relation between the lateral meniscal shapes and the incidence of meniscal tears were studied, and the gender differences in discoid lateral menisci and the similarities of the lateral meniscal shapes in bilateral knees were examined. A total of 602 knees from 306 cadavers were macroscopically analyzed. Altogether, 577 lateral menisci were classified into the following three types: normal type (NM); incomplete discoid type (ICDM); and complete discoid type (CDM). Each lateral meniscus was examined for meniscal tears. The prevalence of a discoid lateral meniscus and gender differences in its prevalence were examined, as were the presence of a meniscal tear for the three types of lateral meniscus. In all, there were 21 (3. 6%) CDM cases and 171 ICDM cases (29.6%). The prevalence of discoid lateral meniscus, including ICDM and CDM, in the female cadavers was significantly higher than that in the male cadavers, but there was no significant gender difference in the prevalence of CDM. It was found that the shape of the lateral meniscus was similar bilaterally. The incidence of meniscal tears for ICDM was significantly higher than that for NM.

Key words Bilateral knees · Cadaver · Discoid lateral meniscus · Japanese · Meniscal tear

Y. Kato (✉) · A. Saito · J. Ryu
Department of Orthopedic Surgery, Nihon University School of Medicine, 30-1 Oyaguchi-Kami-machi, Itabashi-ku, Tokyo 173-8610, Japan
Tel. +81-3-3972-8111; Fax +81-3-3972-4824
e-mail: yuki@cd5.so-net.ne.jp

M. Oshida
Department of Orthopaedic Surgery, Tokyo Teishin Hospital, Tokyo, Japan

S. Aizawa
Department of Anatomy, Nihon University School of Medicine, Tokyo, Japan

Introduction

The knee menisci are C-shaped disks of fibrocartilage interposed between the condyles of the femur and tibia. The biodynamic functions of the meniscus are mainly load transmission, shock absorption, lubrication of the articular surfaces and knee joint, and instability.[1] The unilateral knee has two menisci in the lateral and medial compartments, and the lateral menisci are C-shaped with a diameter less than that of the medial menisci.

Various anatomical anomalies have been described in the lateral meniscus.[2,3] Of these anomalies, the discoid meniscus is a meniscal anomaly that orthopedic surgeons often encounter in general practice. The discoid meniscus presents much more commonly in the lateral compartment. Discoid menisci have been reported more frequently in Asian countries than in other regions of the world.[4–7] After a thorough evaluation of previous reports using Japanese cadaver knees, the reports showed a 5% prevalence of discoid lateral meniscus.[8–11]

Discoid lateral menisci have various sizes and shapes. There are numerous classification systems of the discoid meniscus, such as Smillie's classification[12] and Amako's classification[4] among others. Smillie[12] devised the first classification system and classified the discoid lateral meniscus into three types: primitive, intermediate, and infantile. Amako described his own classification system based on meniscectomy specimens obtained from arthrotomies.

Arthroscopic meniscal surgery has been studied since Watanabe first successfully performed an arthroscopic partial meniscectomy in 1962.[5] Arthroscopic meniscectomy was introduced by Ikeuchi in 1976[13] and by O'Connor in 1977.[14] Due to the rapid and widespread acceptance of arthroscopic surgeries, almost all examinations and treatment for menisci have been performed under arthroscopic control. Watanabe's classification, which was based on arthroscopic findings, has become the accepted classification system.[15]

It is as important to refer to previous reports as it is to look at current treatments and studies based on arthroscopic examinations. In the studies using meniscec-

tomy specimens obtained from arthroscopy,[12,15–18] it is difficult to determine the accurate incidence rate of the discoid lateral meniscus because the indications for arthroscopy have varied among studies presenting incidence rates. Most of previous cadaveric knee studies[8–11] were reported when arthrotomy was mainly performed (before arthroscopy became popular); therefore it is not fair to compare these studies to the recent studies using Watanabe's classification system[15] based on arthroscopic examinations.

The purpose of this study was to determine accurately the prevalence of discoid lateral menisci in Japanese cadaver knees and to investigate the rate of lateral meniscus tears in each lateral meniscal shape using the accepted classification of discoid lateral meniscus from the view point of arthroscopic surgery. There have been only a few reports about bilateral knees or the gender differences in discoid lateral menisci. This article shows the gender differences in discoid lateral menisci and the similarities of the lateral meniscal shapes in bilateral knees.

Materials and methods

Subjects

From 1991 to 2003, the authors observed anatomical specimens used in medical student examinations at Nihon University. Dissection of 602 knees (from 320 male, 282 female) from 306 cadavers (161 males, 145 females) was performed. The average (mean ± standard deviation) age of the cadavers was 77.15 ± 11.25 years (ranging from 42 to 103 years). Altogether, 602 specimens (from 306 cadavers) were observed, of which 558 (from 296 cadavers) were paired. Ten knees were excluded for the following reasons: use in other studies ($n = 7$), total knee arthroplasty ($n = 2$), and amputation ($n = 1$). All cadavers were fixed in 10% formalin before dissection.

Investigation of 306 cadavers (602 knees) was undertaken to establish age, gender, lateral meniscal shape, and presence of tears. All cadaver knees were observed macroscopically, with lateral menisci being classified according to Watanabe's classification. Dissected lateral menisci were categorized into three types: normal type (NM), incomplete discoid type (ICDM), and complete discoid type (CDM).

Procedure for examining knee joints

1. Muscles inserting at the knee joint (biceps femoris, semimembranosus, sartorius, gracilis, popliteus, and gastrocnemius) were removed.
2. Vastus medialis, vastus lateralis, and vastus intermedius were cut about 5 cm above the patella and were reflected distally with the rectus femoris tendon.
3. The joint capsule was incised horizontally at its insertion onto the anterior portion of the femur.
4. The capsule and retinaculum patellae were incised longitudinally on both sides of the patella.
5. The anterior cruciate ligament was resected, and the knee joint was then opened and observed. If necessary, the medial collateral ligament (tibial collateral ligament), lateral collateral ligament (fibular collateral ligament) or popliteus tendon were also removed.

Statistical analysis

Altogether, 577 specimens (from 298 cadavers), in which the shape of the lateral menisci could be determined, were examined for the statistical analysis of the present study.

A nonparametric Kruskal-Wallis test was performed to determine differences in the frequency of tears among the three types of lateral menisci. In addition, a Mann-Whitney U-test and Fisher's exact test were performed to determine differences between two of three lateral meniscal types (CDM and ICDM, CDM and NM, ICDM and NM). Bonferroni's multiple comparison was used for this analysis, with the level of statistical significance being set at $P = 0.05/3$.

(2) Pearson's χ^2 test was used to determine gender-related differences in the frequency of each lateral meniscus shape. Pearson's χ^2 test and Fisher's exact test were used to compare the frequencies of all types of discoid lateral meniscus (ICDM + CDM) and of CDM between men and women.

A value of $P < 0.05$ was considered to indicate statistical significance and all tests were two-tailed. All statistical analyses were performed on a personal computer with the statistical package SPSS for Windows (Version 11.0 J; SPSS, Chicago, IL, USA).

Results

Prevalence of each lateral meniscal shape

Lateral menisci from 577 knees were classified as follows: NM ($n = 385$, 66.7%); ICDM ($n = 171$, 29.6%); CDM ($n = 21$, 3.6%) (Fig. 1). The remaining 25 menisci could not be classified due to loss or previous removal. In these 25 knees (19 cadavers), 12 lateral menisci had disappeared completely and 13 exhibited severe tears.

Gender-related differences in frequency of each lateral meniscal shape

Figure 2 shows the frequencies of discoid meniscus in men and women. In 311 knees from male cadavers, the following results were observed: NM ($n = 229$, 73.6%); ICDM ($n = 73$, 23.5%); and CDM ($n = 9$, 2.9%). In 266 knees from female cadavers, the following results were noted: NM ($n = 156$, 58.6%); ICDM ($n = 98$, 36.8%); and CDM ($n = 12$, 4.5%).

The χ^2 test revealed a significant difference in the frequency of each lateral meniscus shape between men and women ($\chi^2 = 14.504$, df = 2, $P = 0.001$). Moreover, there

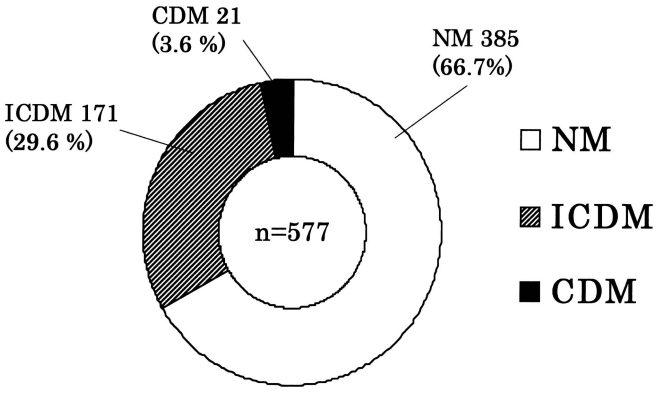

Fig. 1. Prevalence of each lateral meniscal shape. *CDM*, complete discoid meniscus; *ICDM*, incomplete discoid meniscus; *NM*, normal meniscus

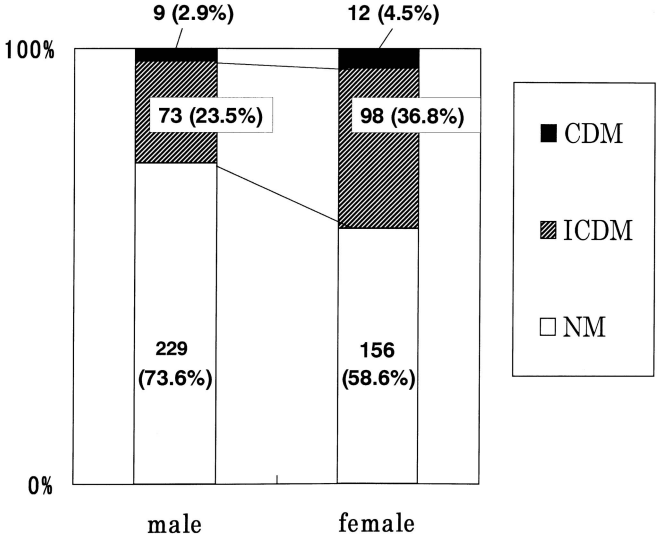

Fig. 2. Frequencies of discoid meniscus in men and women. There was a significant difference in the frequency of each lateral meniscal shape. Women were found to exhibit a significantly higher frequency of lateral discoid menisci (ICDM + CDM), compared to men. However, with regard to the frequency of CDM, no significant difference between men and women was apparent

were significant differences in f the frequency of the discoid lateral meniscus (ICDM + CDM) between men and women revealed by both the χ^2 test ($\chi^2 = 12.566$, df = 1, $P = 0.000$) and Fisher's exact test ($P = 0.001$). Women were found to have a significantly higher frequency of discoid lateral menisci than men. However, no significant difference between men and women was apparent with regard to frequency of CDM on either the χ^2 test ($\chi^2 = 1.069$, df = 1, $P = 0.301$) or Fisher's exact test ($P = 0.374$).

Frequency of tears in each type of lateral meniscus

A lateral meniscus exhibiting tears was found in 94 of 577 knees in which clear classification was possible (Fig. 3). The

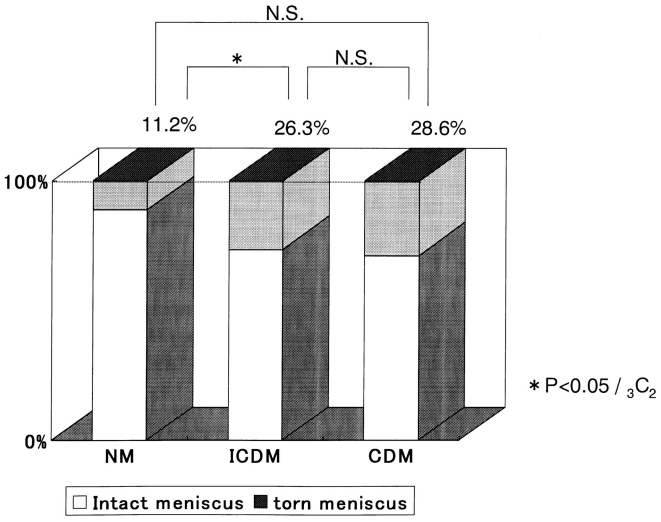

Fig. 3. Frequency of tears in each type of lateral meniscus. There was a significant difference in the ratio of lateral meniscal shapes between the group with torn menisci and that with intact menisci. There was no significant difference between NM and CDM or between ICDM and CDM with regard to the presence of tears. The frequency of tears in ICDM was significantly higher than that in NM

frequency of tears in each lateral meniscal shape (NM, ICDM, CDM) was as follows: 43 (11.2%) of 385 NM; 45 (26.3%) of 171 ICDM; and 6 (28.6%) of 21 CDM.

A nonparametric Kruskal-Wallis test revealed significant differences in the ratio of lateral meniscal shapes between the group demonstrating tears and that with intact menisci ($\chi^2 = 22.331$, df = 2, $P = 0.000$). Bonferroni's multiple comparison using a Mann-Whitney U-test revealed no significant difference between NM and CDM ($P = 0.017$) or between ICDM and CDM ($P = 0.826$). Fisher's exact test revealed no significant difference between NM and CDM ($P = 0.030$) or between ICDM and CDM ($P = 0.798$). However, a Mann-Whitney U test demonstrated a significant difference between NM and ICDM ($P = 0.000$).

Combinations of both lateral menisci in paired knees

Bilateral knees from 279 of 296 cadavers were observed. (Table 1). Examination of paired knees allowed lateral meniscal shape to be clearly classified as follows: (NM/NM), 176 cadavers; (NM/ICDM), 18 cadavers; (ICDM/ICDM), 71 cadavers; (ICDM/CDM), 7 cadavers; (CDM/CDM), 6 cadavers; (NM/CDM), 1 cadaver. Of 279 cadavers, 253 (90.7%) thus had the same shape menisci in both knees.

Discussion

The present study revealed a 3.6% prevalence of complete discoid meniscus in the Japanese sample examined. Smillie[12,18] devised the first classification system for discoid meniscus resulting from an arrest of embryonic develop-

Table 1. Combinations of both lateral menisci in paired knees

Common	No.
Bilateral knees (n = 279)	
NM/NM	176
NM/ICDM	18
ICDM/ICDM	71
ICDM/CDM	7
CDM/CDM	6
CDM/NM	1
Unilateral knee (n = 11)	
NM/?	6
ICDM/?	4
CDM/?	1
Unclear in both knees (n = 6)	
?/?	6
Total	296

NM, normal meniscus; ICDM, incomplete discoid meniscus; CDM, complete discoid meniscus

ment. In an embryonic study, Kaplan[19] described the absence of the posterior meniscal attachment, the so-called Wrisberg-ligament type, and theorized that a normally shaped hypermobile meniscus becomes disk-shaped as the result of mechanical factors. Watanabe described discoid menisci seen thorascopically as being either complete, incomplete, or the Wrisberg-ligament type.[15] The latter classification system, combining elements of both Smillie's and Kaplan's descriptions, has become widely accepted. The Wrisberg-ligament type was described as being fairly normal in size and shape but lacking a posterior attachment other than the ligament of Wrisberg.[20] However, in 1992 Neuschwander[21] recommended that the Wrisberg-variant type should be classified as a lateral meniscal variant with absence of the posterior coronary ligament, because the Wrisberg variant differs from the other two types of discoid meniscus in that the meniscus does not have a true discoid shape. Therefore, dissected discoid lateral menisci were categorized into two types (ICDM and CDM) in this study.

Before arthroscopic examination became widespread, many of the early cadaveric studies were undertaken in Japan, and reported rates of discoid meniscus were between 4.0% and 7.1%.[8–11] However, these early studies involved evaluations different from ours in that they did not take the incomplete type into consideration. In a recent cadaveric study in Japan involving 93 unpaired aged cadaver knees, Ikeuchi[22] reported that 6 complete discoid menisci (6.5%) and 17 incomplete discoid menisci (18.3%) were found. The high incidence (24.7%) of discoid meniscus found by Ikeuchi might be partly explained by the fact that his classification of discoid meniscus included an incomplete type. His study and our own both found the prevalence of the incomplete type of discoid meniscus to be relatively high.

In Korea, Seong and Park[7] dissected 124 adult knees and reported that five discoid lateral menisci (4.0%) were found in five cadavers, three of which were associated with tears. However, this study did not describe the degree of discoid meniscus, and it might not have included incomplete-type abnormalities.

Fewer cadaveric studies have been reported in Western countries. Kaplan[19] reported that observations of anatomical material dissected over a period of 10 years disclosed one cadaver with discoid lateral menisci in both knees; however, no information was provided on the total number of knees. Casscells[23] reported that 15 discoid lateral menisci were found in 300 aged cadaver knees, and that 2 of these specimens represented true discoid meniscus. In a study by Mayer et al., cited by Raber et al.,[24] 15 (5%) of 300 German cadaver knees exhibited discoid meniscus.

In a study by Nemoto[25] of 140 knees from 70 Japanese fetuses aged between 6 and 10 months of gestation, most of the menisci were crescent-shaped, but 3 complete discoid menisci (2.2%) and 19 incomplete discoid menisci (13.6%) were found. Nemoto classified the menisci into five types. Ikeuchi[22] described type 3 and type 4, as classified by Nemoto, to correspond to the incomplete discoid type and type 5 to correspond to the complete discoid type. As the present study showed, results similar to those of Nemoto's evaluation of fetal menisci, it appears that acquired factors are not involved in the formation of discoid lateral meniscus.

The advantage of a cadaveric study is that the prevalence of lateral discoid menisci is unaffected by whether subjects experienced symptoms. In this study, the prevalence of discoid lateral meniscus was higher than that in Western countries. However, incomplete discoid menisci accounted for most cases of discoid lateral menisci reported in this study, which found the complete type of discoid meniscus to occur less frequently than expected. We infer that many cases of discoid lateral meniscus among the Japanese represent incomplete discoid meniscus.

Early studies in Western countries used meniscectomy specimens obtained from arthrotomies and reported the incidence rate is of discoid meniscus at between 2.2% and 4.2%.[12,16–18] In contrast, discoid meniscus has been found to occur with higher frequency in Japan, with early large studies reporting an incidence of between 32.0% and 42.3%.[4,6] The incidence of discoid lateral meniscus was reported to be high in Japan at one time, partly because meniscectomy for the torn medial meniscus was rarely performed.

Similarly, according to recent reports based on arthroscopic examination, there is a significant difference in the incidence of discoid lateral meniscus between Asian countries such as Japan and South Korea (14%–16.6%)[5,7,26] and the West (0.8%–3.5%).[21,27]

The classification used in this study was determined by the amount of tibial plateau covered by the lateral meniscus. Ikeuchi[5,22] clearly defined the incomplete discoid meniscus as covering more than half of the lateral tibial plateau. It might be appropriate to use the incidence of complete-type discoid meniscus when comparing our results to those of previous reports.

In the present study, the rate of complete discoid menisci showed no significant difference between men and women. Furthermore, no previous cadaveric studies have shown as marked a difference in the prevalence of the "complete type" between Western and Asian populations as that implied by the current study.

In our study, discoid lateral menisci (particularly the incomplete type) demonstrated more tears than normal lateral menisci. Bin et al.[28] reported 108 consecutive cases (103 patients) of discoid lateral menisci tears treated by arthroscopy and examined the relation between the tear pattern and the type of discoid meniscus. Simple horizontal tears were found only in the complete type of discoid meniscus, whereas radial, degenerative, and complex tears were found only in the incomplete type. Our study gave similar results in that the incomplete type of discoid meniscus was significantly associated with the development of tears.

Taking these reports into consideration, the incomplete type of discoid meniscus might be more vulnerable than the normal and complete types. One study showed that the susceptibility of the discoid meniscus to damage results from collagen fibers being arranged in directions different from those of the normal menisci at the microscopic level.[29]

Our study of aged cadaver knees indicated that 15 of 21 complete discoid menisci (71.4%) did not demonstrate tears. Dickhaut and DeLee[27] also reported that 10 of 12 complete discoid lateral menisci were intact, were seen as an incidental finding at arthroscopy, and required no treatment. Their study showed that no patients had symptoms attributable to discoid lateral meniscus at an average follow-up of 23 months. In their series, cases of complete type discoid meniscus that required treatment, usually secondary to laceration, were treated by partial meniscectomy, and good results were achieved. It has been reported that untreated symptomatic discoid menisci tend to develop osteoarthritic changes, whereas asymptomatic knees with this abnormality develop few such changes during long-term follow-up.[6] Therefore, instead of simply representing an anomaly, the discoid meniscus might play the same role in factors such as load bearing as the normal meniscus. Symptoms most commonly occur during childhood and adolescence and because our subjects were aged, discoid menisci might have accounted for a large proportion of lateral menisci that were too damaged to be classified. It therefore remains unclear whether some discoid menisci cause symptoms.

Fujikawa[30] stated that he often encountered asymptomatic discoid menisci and objectively confirmed this impression when he examined bilateral knees by arthrography. In short, not all patients with discoid meniscus present with symptoms attributable to this abnormality. Bilateral cases of discoid lateral menisci have been reported,[31] and familial factors have been implicated in such cases.[32] Our study indicated that bilateral knees tend to demonstrate similarity in the lateral meniscal shape; when a discoid meniscus is clinically found unilaterally, the possibility of the other knee having a discoid meniscus is high. Moreover, it seems that symptoms related to a discoid meniscus appear unilaterally despite the discoid meniscus often being found bilaterally. This observation also supports the view that discoid meniscus is not necessarily symptomatic.

Several limitations of this study were recognized. Some authors have reported an increased incidence of meniscal degeneration and cyst formation in discoid meniscus[17] and have suggested that meniscal degeneration is a progressive process. In the present study, we classified as "intact" those lateral menisci in which a tear did not reach the surface or in which degeneration alone was found. Degeneration of complete discoid menisci judged to be intact in our study might have developed at a later stage. Therefore, lateral menisci that we considered to exhibit tears were those we could judge arthroscopically as such. This might have affected the relation between tears and lateral meniscal shape described in this study.

No information was available regarding such factors as the history of sport s activity, injuries, build, or alignment of lower extremities, so these factors were not considered. However, this is thought to represent a limitation of the study related to the use of cadavers. If more detailed information regarding cadavers were available, further evaluation would have been possible. Our study, examining a large number of cadaveric knees and focusing on discoid meniscus in aged cadavers, extends the data available in this field. These results provide a basis for further studies into arthroscopic knee surgery and it is hoped that the results of this study will aid in arthroscopic diagnosis of meniscal lesions, particularly lateral discoid meniscus.

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