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Reliability of a New Arthroscopic Discoid Lateral Meniscus Classification System

A Multicenter Video Analysis

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Background: The discoid lateral meniscus (DLM) is one of the most common congenital anomalies of the knee. The pathomorphology of DLM varies. Current classification systems are inadequate to describe the spectrum of abnormality.

Purpose: A study group of pediatric orthopaedic surgeons from 20 academic North American institutions developed and tested the reliability of a new DLM classification system.

Study Design: Cohort study (diagnosis); Level of evidence, 3.

Methods: After reviewing existing classifications, we developed a comprehensive DLM classification system. Four DLM features were evaluated: meniscal width, meniscal height, peripheral stability, and meniscal tear. Stepwise arthroscopic examination using anteromedial and anterolateral viewing portals was established for evaluating these features. Three senior authors who were not observers selected 50 of 119 submitted videos with the best clarity and stepwise examination for reading. Five observers performed assessments using the new classification system to assess interobserver reliability, and a second reading was performed by 3 of the 5 observers to assess intraobserver reliability using the Fleiss κ coefficient (fair, 0.21-0.40; moderate, 0.41-0.60; substantial, 0.61-0.80; excellent, 0.81-1.00).

Results: Interobserver reliability was substantial for most rating factors: meniscal width, meniscal height, peripheral stability, tear presence, and tear type. Interobserver reliability was moderate for tear location. Intraobserver reliability was substantial for meniscal width and meniscal height and excellent for peripheral stability. Intraobserver agreement was moderate for tear presence, type, and location.

Conclusion: This new arthroscopic DLM classification system demonstrated moderate to substantial agreement in most diagnostic categories analyzed.

Keywords: classification; knee; discoid lateral meniscus; meniscal height; meniscal tear; meniscal width; peripheral stability

Discoid lateral meniscus (DLM) is one of the most common congenital anomalies of the knee. An estimated 5% of the population has a discoid meniscus.[15,25] The true prevalence, however, is unknown because DLM is often asymptomatic, and substantial heterogeneity exists in the pathomorphology. On one end of the spectrum is asymptomatic DLM, with minimally increased width and height as compared with a normal meniscus and stable peripheral capsular attachments. On the other end of the spectrum is DLM with markedly increased width and height, coupled with absent capsular attachments, which leads to mechanical symptoms. Between is a range of asymptomatic and symptomatic menisci with varying width, height, tearing, and capsular attachment stability. This heterogeneity can make description and classification of the DLM difficult.

The commonly used Watanabe classification provides a basis for understanding DLM but does not capture the full spectrum of discoid meniscal pathomorphology.[28] This classification system categorizes menisci as being complete (type I) or incomplete (type II) or as having posterior peripheral instability (type III), often referred to as the "Wrisberg variant." The first 2 categories focus on overall meniscal width and coverage of the lateral tibial plateau, whereas the last category focuses on the absence of posterior capsular attachments. However, published discoid meniscus series note a paucity or complete absence of type III discoid menisci.[1,7] This effectively means that most DLMs are classified as type I or II, distinguished

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solely on the basis of meniscal width. Menisci with absent capsular attachments in the anterior horn, midbody, or both may be unstable but do not necessarily qualify as type III. Thus, the categories are not mutually exclusive and leave many critical clinical features of the 3 types incompletely characterized. Although the Watanabe classification system has long been used to describe DLM, clear differentiation of the spectrum of discoid menisci requires a more descriptive classification system.

Because of the wide spectrum of DLM pathomorphology, reported treatments and their outcomes vary substantially. Historically, DLM was commonly treated with total meniscectomy.[9,13] In contrast, current techniques typically aim to "saucerize" or debride the central portion of the meniscus, preserving a peripheral rim of meniscus and stabilizing the remaining peripheral meniscal tissue as needed.[11,14,17] However, the technical principles of saucerization and stabilization are not universally agreed on. Some surgeons, citing the lack of benefit of meniscal repair, recommend saucerization without stabilization.[22,26] Others report good outcomes with repair and stabilization without saucerization.[14,16] These varied treatment approaches result in a range of outcomes. Excellent outcomes have been achieved in some series,[21,22] whereas arthritic changes have been identified in others.[1,12,20] It is unclear whether this variation in outcomes is attributable to the different surgical techniques used or the diverse spectrum of pathology being treated. A more descriptive classification system would identify the type of discoid menisci being treated and determine the most appropriate treatment.

A study group of pediatric orthopaedic surgeons from 20 academic institutions in North America developed and tested the reliability of a new Pediatric Research in Sports Medicine (PRiSM) DLM classification system with the goal of standardizing descriptions of pathology to facilitate research, guide treatment, and ultimately improve outcomes of DLM.

METHODS

This study was approved by our local institutional review board. The PRiSM DLM classification system was developed through a comprehensive initial review of existing classification systems,[2,11,17,28] followed by a nominal group technique consensus method to determine the key DLM characteristics and subcategories. Four main features were included: meniscal width, meniscal height, peripheral stability, and meniscal tear (Table 1, Figure 1). A pilot study was performed to refine areas of less-than-moderate interobserver reliability in the initial classification system. A stepwise arthroscopic examination before and after central zone saucerization, using anteromedial and anterolateral viewing portals, was established to evaluate DLM features.

Width was categorized as incomplete or near-complete/complete coverage of the lateral tibial plateau. In the incomplete subcategory, the DLM covers <90% of the lateral tibial plateau (Figure 2A), and in the near complete/complete subcategory, the DLM covers ≥90% (Figure 2, B and C). In the pilot study, incomplete discoid menisci were subdivided according to the amount of tibial plateau coverage. However, it was determined by consensus that subclassifying incomplete versus nearly complete was not as important as distinguishing between the original Watanabe types I and II. Thus, the category of "near complete" was combined with the "complete" category, given the lack of differentiation among other features of discoid menisci that were near complete, which were consistently addressed with the same treatment principles as complete discoid menisci.

Height or "thickness" was categorized as normal or abnormal. Meniscal thickness was evaluated in reference to the relative femorotibial joint space. Again, because of the broad range of normal meniscal heights and the likely influence of knee size, we avoided a numerical measurement or even a percentage increase in perceived height. A discoid meniscus of normal height was therefore deemed to have thickness appropriate for the femorotibial joint space and to taper centrally (Figure 3A). A meniscus of abnormal height had excessive thickness for the femorotibial joint space or lacked gradual central tapering (Figure 3, B and C).

Stability was assessed via arthroscopic probing from the anteromedial and anterolateral portals and categorized as

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TABLE 1
PRiSM Lateral Discoid Meniscus Classification System[a]

Classification	Definition
Width	
W0	Normal
W1	Incomplete: wider than normal, <90% tibial plateau covered
W2	Near complete/complete: ≥90% tibial plateau covered
Height	
H0	Normal height: thickness appears identical to that of a normal meniscus
H1	Abnormal height: thickness is greater than that of a normal meniscus
Stability	
S0	Normal stability
SA	Abnormal stability[b] in the anterior half of meniscus
SP	Abnormal stability[b] in the posterior half of meniscus
SAP	Abnormal stability[b] in the anterior and posterior halves of the meniscus
Nonvertical tears[c]	
T0	No tear or tear in central portion/ saucerization zone
THA	Horizontal tear[d] in anterior half
THP	Horizontal tear[d] in posterior half
THAP	Horizontal tear[d] extending into anterior and posterior halves
TDA	Degenerative/complex/radial tear in anterior half
TDP	Degenerative/complex/radial tear in posterior half
TDAP	Degenerative/complex/radial tear in anterior and posterior half

[a]PRiSM, Pediatric Research in Sports Medicine.

[b]Abnormal stability can be secondary to absent meniscocapsular attachments, present but lax/deficient attachments (meniscus translates past the midpoint/apex of the convexity of the lateral femoral condyle), or a vertical tear of the peripheral meniscus or meniscocapsular attachment.

[c]Location of tear categorized as anterior or posterior according to where most of the tear is located. Combined anterior/posterior subcategory for the tears that extend past the midpoint/midbody into the other horn.

[d]Horizontal cleavage: >5 mm of horizontal width and depth >50% of retained meniscus or extending into the vascular "red-red" zone.

normal or abnormal. Abnormal stability was deemed present (1) if meniscocapsular attachments were absent, (2) if meniscocapsular attachments were deficient and allowed the meniscus to translate past the midpoint/apex of the convexity of the lateral femoral condyle with probing, or (3) if the peripheral meniscus or meniscocapsular attachment had an unstable vertical tear. Normal stability was the absence of these 3 criteria. Abnormal stability was subclassified by location. Abnormal stability was considered "anterior" if it involved primarily the anterior horn, with or without associated instability of the midbody, but did not extend to the posterior horn (Figure 4, A and B). Abnormal stability was considered "posterior" if it involved primarily the posterior horn, with or without instability of the midbody, but did not extend to the anterior horn (Figure 4, C and D). If the anterior and posterior horns were both involved, then abnormal stability was classified as "anterior/posterior." Abnormal stability centered in the midbody was classified as anterior or posterior, depending on which half demonstrated the predominant instability.

Meniscal tears were classified by presence, type, and location (Figure 5A). Tears were present if they were located within the peripheral retained meniscus, but they were not considered present, for the purpose of classification, if they were located in the central resected zone (Figure 5, B-D). Among tear types, "horizontal cleavage" tears referred to those with >5 mm of horizontal width and a depth >50% of the retained meniscus or to those extending into the vascular "red-red" zone or peripheral third of the region of a normal meniscus (Figure 5, E and F). Other tear types included radial, complex, or severely degenerative. "Radial" tears were defined as those oriented perpendicular to the circumferential meniscal fibers; "complex" tears were those with >1 tear type; and "degenerative" tears were those that had nondiscrete or frayed edges with loss of meniscal tissue. As with stability, tears were categorized as "anterior," "posterior," or "anterior/posterior" according to the predominant location of the tear. The combined anterior/posterior subcategory was used for the anterior or posterior horn–based tears that extended past the midbody into the other horn or clear midbody radial tears.

Sample size estimates for raters and patients were developed through an a priori power analysis. Based on a model of 4 categories, at least 40 representative arthroscopic videos were needed for evaluation by 5 orthopaedic surgeon raters (J.J.B., M.D.M., C.J.F., V.E.J., Z.S.S.). From a set of 119 arthroscopic videos recorded during treatment of symptomatic discoid menisci submitted for review, 50 were selected by 3 senior authors (nonobservers R.J.L., J.J.N., B.E.H.) to ensure adequate statistical power and a variety of pathological types. The median age of patients was 11 years (range, 3-19 years), and 33 were female. All selected videos were screened for clarity and completion of the stepwise examination. These videos were numbered sequentially and shared via an internet-based file-sharing system. A separate group of 5 authors (observers J.J.B., M.D.M., C.J.F., V.E.J., Z.S.S.)—all of whom were fellowship-trained pediatric sports medicine surgeons and had experience treating discoid meniscus—assessed the 50 videos using the classification system in a pilot. After the pilot, a group discussion including the 5 observers was held using a sample of arthroscopic videos outside the final bank of 50 videos to refine the classification scheme. The same 5 observers then performed a final review. Four weeks elapsed between the pilot and final reviews. Between reviews, the sequence of the arthroscopic videos was randomized. All observers were involved in the discussion of classification refinement after the pilot. Three of the 5 observers performed a repeat reading of 50 videos, the sequence of which was again randomized, >4 weeks after the initial reading to minimize recall bias.

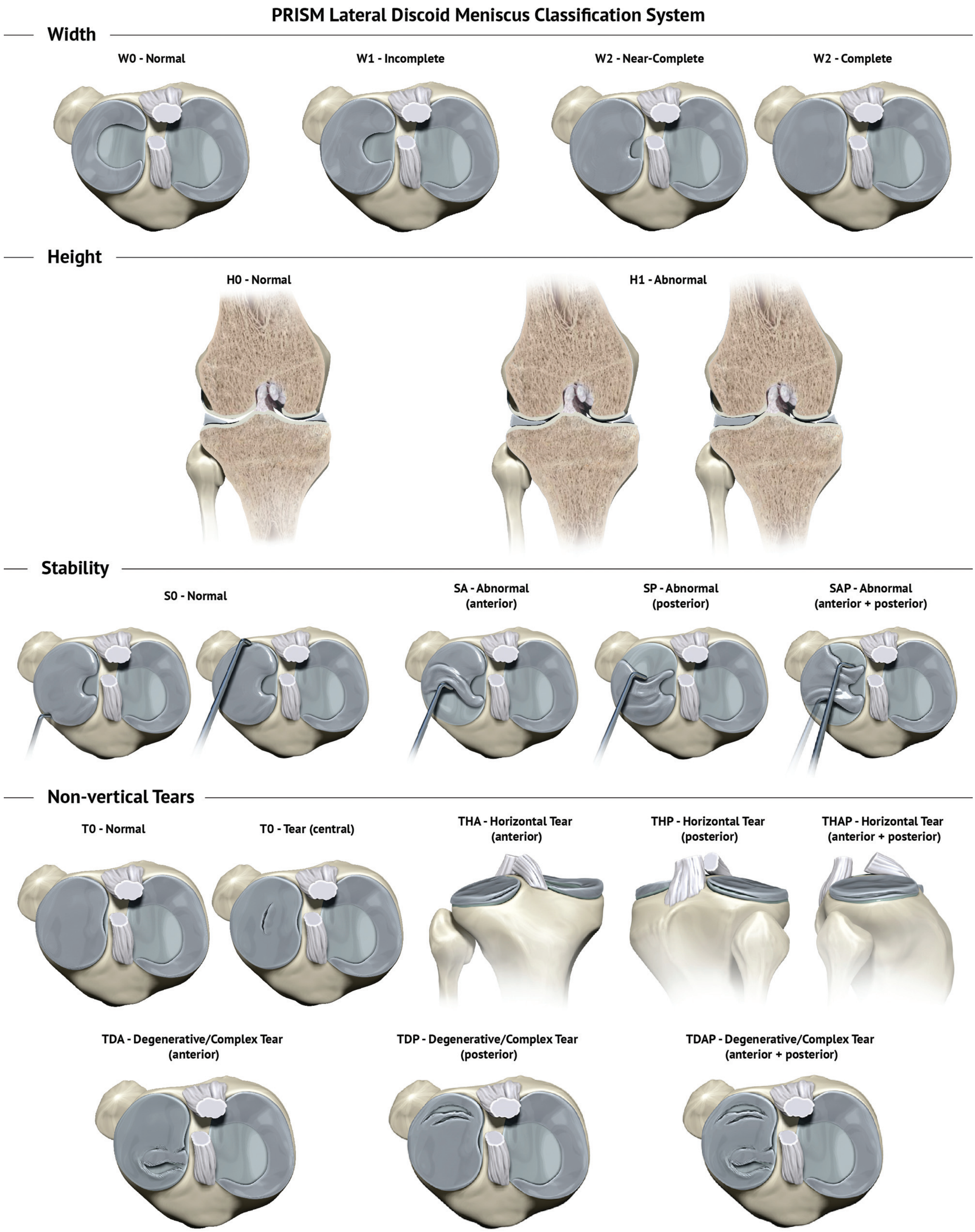

Figure 1. Pediatric Research in Sports Medicine (PRiSM) lateral discoid meniscus classification system.

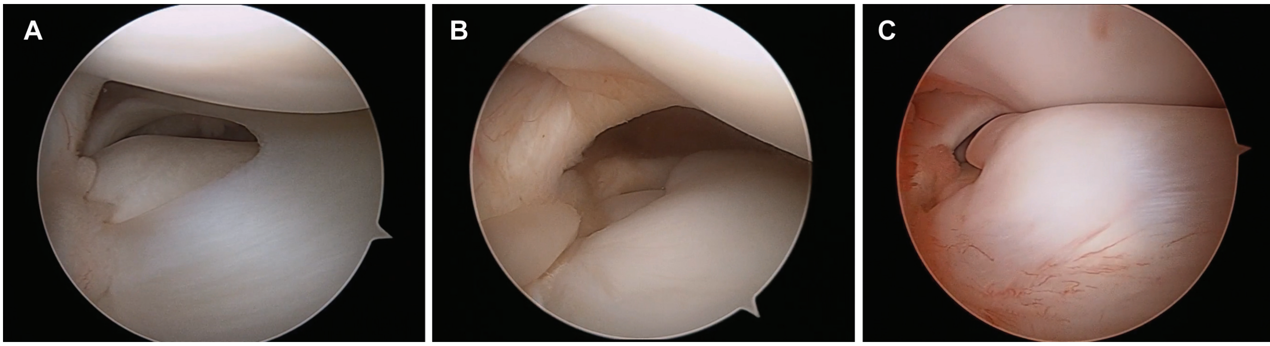

Figure 2. Discoid meniscal width: (A) incomplete, (B) near complete, and (C) complete.

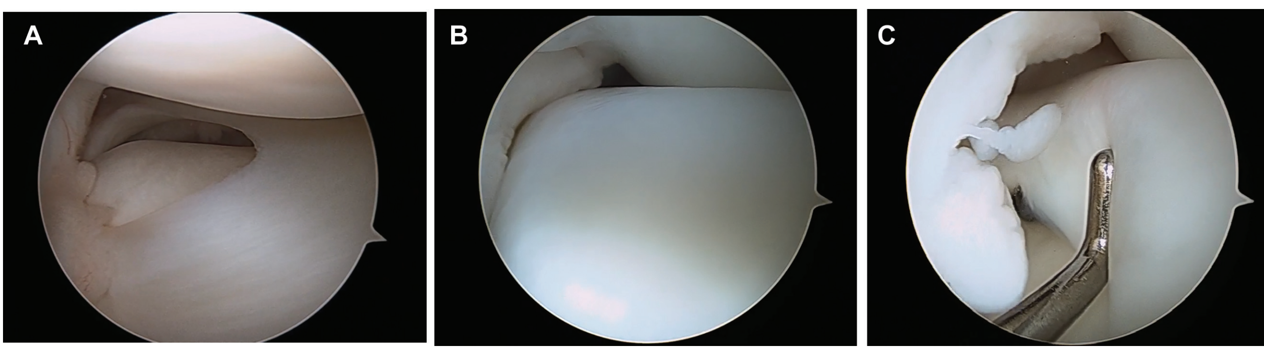

Figure 3. Discoid meniscal height: (A) normal height and (B) abnormal height abutting the anterior cruciate ligament and covering the tibial articular surface (C) with a 5-mm probe for height reference.

Inter- and intraobserver reliabilities of the rating factors were assessed using the Fleiss κ coefficient designed for multiple observers with nominal variables (reliability classification: fair, 0.21-0.40; moderate, 0.41-0.60; substantial, 0.61-0.80; and excellent, 0.81-1.00).[19]

RESULTS

Interobserver reliability was substantial for most rating factors: meniscal width (incomplete, near complete/complete), meniscal height (normal, abnormal), peripheral stability (normal, abnormal anterior, abnormal posterior, abnormal anterior/posterior), tear presence (yes, no), and tear type (horizontal, radial/complex/degenerative). Intraobserver reliability was substantial for meniscal width and meniscal height and excellent for peripheral stability. Interobserver agreement was moderate for tear location (anterior, posterior, anterior/posterior), and intraobserver agreement was moderate for tear presence, tear type, and tear location (Table 2).

Of the 50 videos, 26 had agreement by all 5 reviewers in at least 3 categories. The most common categories of disagreement were, in descending order of frequency, tear type and location, meniscal height, instability, and meniscal width. Nine menisci had agreement by all 5 reviewers in all 4 categories. Of the 9 menisci with complete agreement, 4 were incomplete with normal height, normal stability, and no tear or a tear in the central zone. Of the 9 discoid menisci with complete agreement, 8 did not have a tear. One of the 50 videos lacked agreement in all 4 categories, with observers split on width, height, presence of anterior instability, and presence of a posterior horizontal tear (Table 3).

DISCUSSION

We developed a new arthroscopic DLM classification system that includes the features of meniscal width, adds the attribute of meniscal height, and delineates peripheral instability and tear characteristics to improve the ability to define, discuss, and investigate discoid meniscal pathology. This new DLM classification system showed substantial interobserver reliability across most of the 4 categories and substantial or excellent intraobserver reliability in 3 of 4 categories.

Meniscal width was the focus of the first 2 categories of the Watanabe classification, with type I (complete) and type II (incomplete) discoid menisci. The first category in the currently proposed DLM classification mirrors the Watanabe classification in assessing width and demonstrated substantial inter- and intraobserver agreement. To accommodate the range in knee size among pediatric

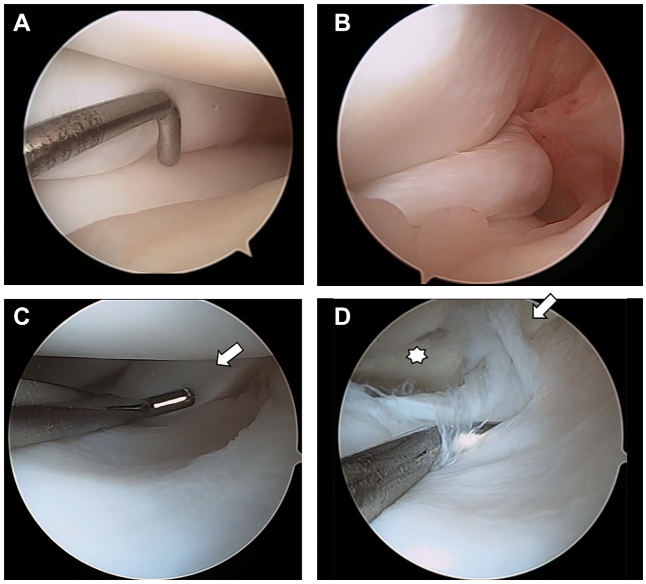

Figure 4. Abnormal stability in the anterior half of discoid meniscus with absent meniscocapsular attachments in the (A) anterior horn and (B) midbody. Abnormal stability in the posterior half of meniscus with insufficient meniscocapsular attachments in the (C) posterior horn despite normal appearance, (D) displaced anteriorly by a probe. Asterisk, capsule; arrow, popliteus.

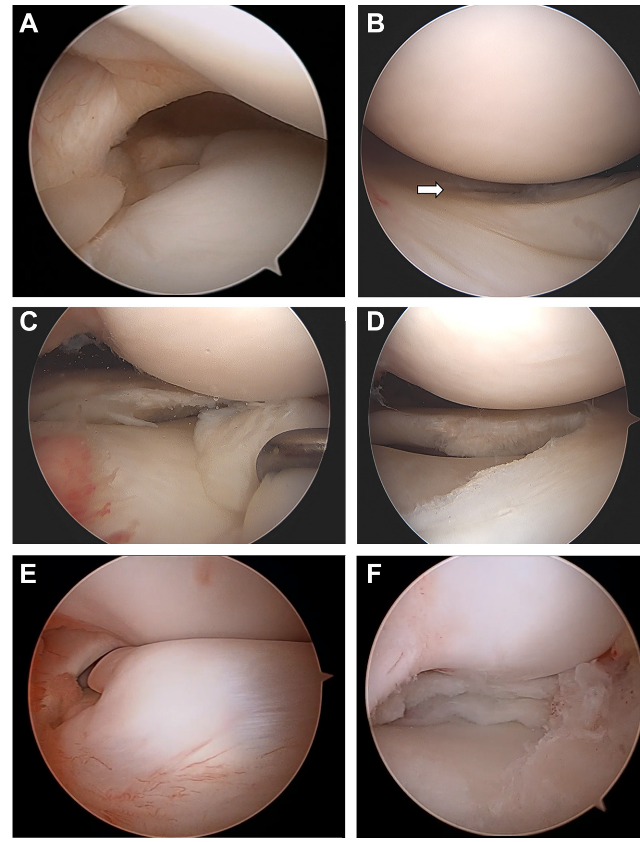

Figure 5. Discoid meniscus (A) without a tear, (B) with a tear (arrow) in the central portion/saucerization zone, (C) with the central meniscus displaced by probing, and (D) after saucerization demonstrating the absence of a tear in the retained meniscus. Discoid meniscus with a horizontal tear in the posterior half (E) before and (F) after saucerization.

patients, we used the percentage of tibial plateau coverage, as others have used in diagnostic imaging,[8,24] instead of a fixed-width measurement in millimeters. The pilot category that differentiated among subtypes of incomplete menisci referenced whether the central meniscus crossed the apex of the lateral femoral condyle. That characteristic, however, was found not to be fixed, because meniscal position and plateau coverage vary by knee position during arthroscopy. Additionally, the percentage of normal meniscal coverage of the tibia in the coronal plane decreases with age, adding further variability to what is considered normal.[6] The feature of meniscal tear added yet another variable to the relative position of the central edge of the meniscus. A previous subcategory of “near complete” that was used in the pilot review led to poor interobserver agreement and was combined with the “complete” category to better align with the distinction between the original Watanabe types I and II. With the refined criteria, we showed substantial inter- and intraobserver reliability for width. Although by definition a discoid meniscus is of abnormal width, addition of the normal-width category in the final classification system was made for comprehensive inclusion of potential discoid meniscal pathology. Because controversy remains about whether to saucerize a DLM, categorizing DLM according to width will help future studies determine which menisci may be suitable for preservation of meniscal width and which may be at higher risk of further tearing or symptom recurrence.

Abnormal meniscal height likely is a factor in the classic presentation of a “snapping knee.” Greater meniscal thickness may interfere with normal femoral condyle and tibial plateau motion, particularly during deep squatting with rotation, leading to intrasubstance meniscal degeneration or peripheral tearing. Although it is a key characteristic of DLM, discoid meniscal height is excluded from the Watanabe classification. The proposed new DLM classification used height as the second feature. However, abnormal discoid meniscal height is difficult to define. Normal meniscal height has traditionally been considered 4 to 5 mm,[15] whereas a more recent magnetic resonance imaging–based study reported a range in heights (2-11 mm) in children.[6] Ultimately, this DLM classification categorized height with the binary distinction of “normal” or “abnormal,” defining abnormal meniscal height as present if the thickness of the peripheral component was greater than what would be expected relative to the tibiofemoral joint space or if it lacked the expected taper centrally. With this definition, most DLMs in the current series were considered abnormal, except those with a minimal increase in central width without an increase in peripheral height. With this refined definition of meniscal height, substantial inter- and intraobserver reliability for height was

TABLE 2
Inter- and Intraobserver Reliability

Factor	Fleiss κ (95% CI) Interobserver	Intraobserver
Meniscal width/surface area	0.75 (0.66-0.84)	0.79 (0.63-0.95)
Meniscal height	0.62 (0.53-0.71)	0.64 (0.48-0.80)
Stability classification	0.71 (0.65-0.77)	0.82 (0.71-0.93)
Tear		
Presence	0.69 (0.61-0.78)	0.60 (0.44-0.76)
Type	0.62 (0.55-0.69)	0.56 (0.44-0.68)
Location	0.51 (0.45-0.57)	0.49 (0.38-0.59)

achieved. With more granularity, future studies may elucidate the clinical relevance of discoid meniscal height.

As with meniscal height, peripheral rim instability may be a key factor in the presentation of snapping knee.[18] Because instability is associated with presentation at a younger age,[17] abnormal anterior or posterior translation of the DLM may be a strong determinant of DLM symptoms. Despite this, no consensus exists on the need for meniscal stabilization. Some advocate for stabilization to be performed in isolation, without saucerization, and with good outcomes.[14,16] Others recommend saucerization alone, without repair.[22,26] Heterogeneity in the types of DLM selected for each treatment method may explain the variability in treatment preferences. In the present study, a broad definition was required to define peripheral instability. This definition included perceived congenital absence of attachments, as identified in Watanabe type III, as well as vertical tears in the peripheral meniscus resulting in instability. These combined inclusion criteria critically acknowledge the difficulty of distinguishing chronic remodeled tears from congenital absence of ligamentous stabilizers. There may be a spectrum of instability, from congenital absence of the meniscocapsular attachments to vertical tearing of the peripheral meniscus, which currently cannot be accurately subcategorized on the basis of imaging or arthroscopy, despite numerous efforts. Many DLMs may fall in the intermediate range of stability, wherein a thin rim of capsular attachments is difficult to distinguish as a congenital deficiency vs remodeled adhesions of chronic tear. Nevertheless, pathologies would be similar because translation of the meniscus beyond the central condyle denotes poor meniscal function and high risk for further degeneration. Additionally, midbody instability, although an original subcategory in the classification system, was excluded because none of the 119 discoid meniscal videos demonstrated true isolated lateral or midbody instability. The presence of midbody instability was always paired with anterior or posterior instability. When considering how classification may guide treatment, we believe that surgical technique would likely be dictated by whether midbody instability is more anterior or posterior. Thus, we categorized menisci as anterior or posterior according to instability, rather than anterior horn, midbody, and posterior horn. Conceptually, excluding the isolated midbody category was reasonable because

TABLE 3
Frequency of Discoid Meniscal Features by 250 Observations

Classification Component	% (No.)	Range, %
Meniscal width/surface area		
Incomplete	50 (125)	40-56
Near complete/complete	50 (125)	44-60
Meniscal height		
Normal	46 (115)	40-50
Abnormal	54 (135)	50-60
Instability		
Normal stability	47 (117)	32-52
Abnormal stability		
In anterior half of meniscus	19 (47)	18-20
In posterior half of meniscus	29 (73)	26-34
In anterior and posterior meniscus	5.2 (13)	2-16
Tear type		
No tear or tear in central portion/ saucerization zone	62 (155)	54-76
Horizontal	25 (62)	16-38
Degenerative/complex/radial	13 (33)	6-24
Tear location		
No tear or tear in central portion/ saucerization zone	62 (155)	54-76
Anterior half	4.4 (11)	0-10
Posterior half	20 (50)	10-28
Anterior and posterior halves	14 (34)	4-20

unstable menisci tend to extrude anterior or posteriorly but not centrally. For these reasons and because inclusion of the midbody category decreased intra- and interrater reliability, we deemed the category unnecessary. After the combination of congenital and tear-related instability and the elimination of a midbody instability category, substantial interobserver and excellent intraobserver reliability values were demonstrated. This classification highlights the need to assess anterior instability dynamically, specifically by viewing through the anteromedial portal. Although posterior instability can be assessed through a Gillquist maneuver and a 30° or 70° arthroscope or with posterior portals, we determined that the anterior portal evaluation after saucerization was sufficient. The findings of this study suggest that assessing anterior and posterior peripheral stability intraoperatively should be a defining feature of future studies to clarify the clinical importance of DLM stabilization.

Comprehensive characterization of a discoid meniscal tear likely requires multifaceted evaluation of height, width, and stability. Furthermore, chronicity of symptoms may be a factor in the severity of tearing, whereas width, height, and congenital peripheral stability influence the tear type or pattern via the magnitude and vector of forces imposed on the discoid meniscus.[11,18] Although the central meniscus is avascular,[4,23] and therefore susceptible to degenerative tears because of its collagen disorganization,[5,23] this classification system focuses on recognizing only the tearing that remains present after saucerization in the retained meniscal tissue. This exclusion exists largely because saucerization is commonly performed to remove the central component, which makes tears involving the saucerized portion clinically unimportant because of a lack of influence on function or natural history of the retained meniscus. Conversely, for tears arising in or extending to the retained peripheral tissue, the tear type and tissue quality greatly influence the success of arthroscopic repair and may predict a patient's long-term clinical outcome. Horizontal cleavage tears are frequently present in DLMs and were classified separately from other tears. Group consensus suggested that horizontal cleavage tears may have a different early pathophysiology than other tear types and may be secondary to the inherent disorganization of the collagen fibers predisposing the DLM to intrasubstance cleavage.[23] The remaining tear patterns were grouped, and the system demonstrated substantial interobserver reliability with presence of tear and tear type whereas tear location showed moderate agreement. Moderate intraobserver agreement was noted for all tear characteristics. These results are similar to those in studies of arthroscopic classification of adult meniscal tears[3,10,27]: fair interobserver reliability for involvement of the central vs peripheral meniscus, substantial interobserver reliability for anterior and posterior location, and moderate and substantial interobserver reliabilities for tear type.

The current study suggests some limitations to the new DLM classification system. Recall bias can still be present despite elapsed time between video reviews and randomization of video order. Several continuous variables (width and height) were presented as categorical variables. Ideally, a classification system would consider a numerical value, such as exact percentage of coverage of the tibial plateau or ratio of height as compared with a normal meniscus. The proposed categorical variables demonstrated substantial interrater agreement and are simple to use in research and clinical settings. Also, despite the heterogeneity of instability and tears, this system does not assess all aspects of the morphopathologic qualities. However, the classification system could be modified in the future to define instability and tear characteristics with greater detail as improvement in defining characteristics increases. Although moderate or substantial agreement was demonstrated for tear presence, type, and location, improved descriptors may yield better agreement in the future. Given the limited ability of arthroscopic video review to provide the tactile feedback often used during intraoperative stability assessment, the study may underestimate the reliability of the classification scheme when performed during arthroscopy in real time, as in clinical practice. Despite these limitations, this is the first DLM classification system to be proposed and evaluated for reliability.

The new PRiSM arthroscopic DLM classification system categorizes several morphopathologic characteristics critical to prognosis and treatment decisions. The 4 features of width, height, instability, and meniscal tear demonstrated substantial interobserver agreement. This classification system provides a basis for future large-scale multicenter studies designed to refine our knowledge and guide evidence-based treatment of DLM.

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