

## CONSENSUS

# Chinese Experts Consensus and Practice Guideline on Discoid Lateral Meniscus

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Discoid lateral meniscus (DLM) is the most common congenital variant of the lateral meniscus, which is prone to degeneration and lesions, and often leads to knee osteoarthritis. At present, there is no consensus on the clinical practice of DLM, and this expert consensus and practice guidelines on DLM was developed and approved by Chinese Society of Sports Medicine according to the Delphi method. Among 32 statements drafted, 14 statements were excluded for redundant information, and 18 statements achieved consensus. This expert consensus focused on the definition, epidemiology, etiology, classification, clinical manifestations, diagnosis, treatment, prognosis, and rehabilitation of DLM. Restoring the normal shape, retaining appropriate width and thickness, and ensuring the stability of the remnant meniscus is critical to sustaining the physiological function of the meniscus and preserving the knee. The partial meniscectomy with or without repair should be the first-line treatment when possible, given that the clinical and radiological long-term outcomes of total or subtotal meniscectomy are worse.

**Key words:** Consensus; Diagnosis; Discoid Lateral Meniscus; Guideline; Treatment

## Introduction

Normal lateral meniscus (NLM) plays a vital role in knee biomechanics, such as distributing loads and protecting the articular cartilage.<sup>1</sup> Discoid Lateral Meniscus (DLM) is the most common congenital variant of the lateral meniscus, which was first reported by Young in 1889.<sup>2</sup> The incidence of DLM is 3%–5% in the Western population and 10.9%–16.6% in the Asian population, with racial and regional differences.<sup>3–5</sup>

The proportion of patients with bilateral DLM in the DLM population is as high as 79%–97%.<sup>6</sup> Morphologically, DLM is broad and disc-like in appearance, losing the semilunar shape of NLM, and covering more than 70% of the lateral tibial plateau.<sup>7,8</sup> Histologically, the circular collagen fiber of DLM is sparse and disordered. Clinically, DLM is often accompanied by potential peripheral rim instability, dysplasia of lateral femoral condyles, and abnormal lower limb axial alignment.<sup>1,3,9–21</sup>

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These pathophysiological features of DLM enable it to be prone to degeneration, lesions, and retear after arthroscopic surgery, usually presenting as symptoms such as pain, swelling, snapping, locking, giving way, or limited motion.<sup>22–24</sup> As the condition progresses, it often combines with articular cartilage lesions or degeneration, and knee osteoarthritis will occur.<sup>23,25–28</sup>

The differences between DLM and NLM in morphology, histology, clinical features, diagnosis, and treatment are significant.<sup>1,3,4,29</sup> The etiology and pathogenesis of DLM are currently unclear, and there are still many controversies regarding its definition, epidemiology, classification, and treatment.<sup>1,3,30–32</sup> Such factors as age, BMI, clinical manifestations, morphology, peripheral rim instability, lesion location and type, quality of remnant meniscus, state of articular cartilage, etc. play an essential role in developing treatment planning and predicting prognosis.<sup>27,28,31,33–36</sup> Unfavorably, there is no expert consensus on the above issues worldwide, which challenges the clinical diagnosis and treatment of DLM.

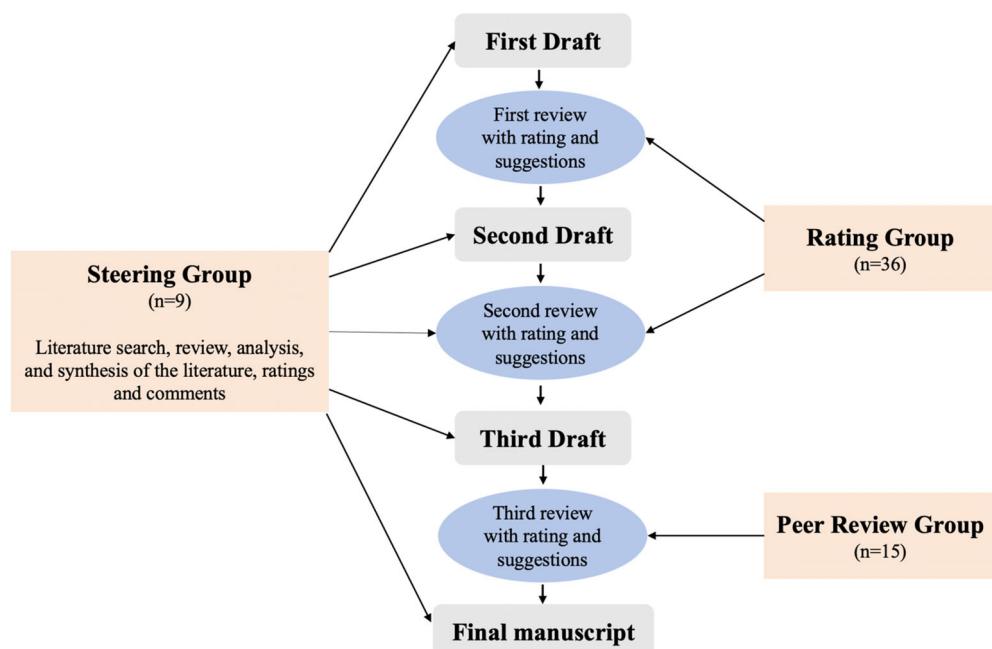
Given the particularity of DLM and the controversy of many clinical problems, the China Sports Medicine Association (CSMA) developed the “Chinese Experts Consensus and Practice Guideline on Discoid Lateral Meniscus” for clinical reference. This consensus is conducive to promoting the understanding of DLM, improving the decision-making process, and effectively elevating the long-term clinical efficacy of DLM patients.

## Materials and Methods

CSM established the expert consensus for DLM from July 31, 2021, to December 26, 2021, focusing on the definition, epidemiology, etiology, classification, clinical

manifestations, diagnosis, treatment, prognosis, and rehabilitation. NLM lesions will be discussed in another consensus.

The process of this consensus followed the Delphi method (Figure 1). A total of 60 experts with extensive experience in the fields of sports medicine and orthopaedics were invited and divided into the steering group (n = 9), the rating group (n = 36), and the peer review group (n = 15). First, the steering group developed a series of statements (question and answer sets) based on a comprehensive literature review from such databases as PubMed, Embase, Web of Science, Cochrane Central Register of Controlled Trials, and the Cochrane Library. The medical subject headings (MeSH) or text words used were as followings: [discoid meniscus], [definition], [demographics], [epidemiology], [etiology], [classification], [type], [diagnostic], [magnetic resonance imaging], [MRI], [X-ray], [ultrasound], [ultrasonography], [tear], [lesion], [trauma], [incidence], [location], [treatment], [arthroscopy], [repair], [suture], [saucerization], [meniscoplasty], [reshaping], [meniscectomy], [prognosis], [rehabilitation], etc. which were combined with Boolean Operators: AND and OR. References in the identified studies were searched for relevant studies. Animal studies were excluded. The statements were drafted to address the controversy about DLM: (1) definition, epidemiology, and etiology of DLM; (2) pathological features of DLM and mechanisms of DLM lesions; (3) classification of DLM and its lesions; (4) diagnosis, clinical manifestations, physical examination, and imaging examination of DLM and its lesions; (5) the indications of conservative treatment and surgical interventions; (6) the surgical planning for DLM; (7) prognostic factors; (8) rehabilitation. The quality of the statements was graded by steering group based on the quality of the available studies and was sorted into the appropriate grade of



**Fig 1** Flowchart of the procedure determining the consensus for discoid lateral meniscus

recommendation.<sup>37</sup> Grade A1, multiple ( $\geq 2$ ) level 1 evidence randomized controlled trials (RCT) with similar findings or one meta-analysis; grade A2, one level 1 evidence RCT; grade B1, prospective cohort study; grade B2, comparison between groups but not a level 1 RCT; grade C, case series; grade D, case report; grade E, expert opinion/basic research.

Afterward, these statements were submitted to and reviewed by the rating group. Based on the scientific evidence and the clinical experience of raters, each member of the rating group was asked to anonymously score each statement on a Likert scale ranging from 1 (totally inappropriate) to 5 (totally appropriate) points. Then, according to the voting result and the discussion of the rating group, the statements were endorsed or revised correspondingly. If the proportion of favorable votes was 80% or above, the statement was defined as the consensus, and its content needed to be revised if inconsistent opinions were proposed and supported by the other two participants. If 50% or less, the issue was not passed. If between 50% and 80%, the statement with its suggestion was returned to the steering group for revision, and the second draft was prepared and resubmitted to the rating group for discussing and voting again at the steering and rating group's combined meeting. Once the consensus was reached between the steering and rating groups, the comments were sent to the steering group for the third draft. Finally, the third draft was sent to the peer review group to evaluate and determine the feasibility, accessibility, and readability of the proposed recommendations.

## Results

Studies about DLM have relatively low scientific quality. The steering group drafted 32 statements on DLM. After the first review by the rating group, 14 statements were excluded for redundant information. Finally, 18 statements achieved consensus, of which 16 statements were unanimity. The mean point assigned by each rater ranged from 4.69 to 4.97 points. The mean point by the rating group was 4.86 (95% CI 4.81–4.90).

## Statements

### *The Definition of DLM*

DLM is the most common congenital variation of the lateral meniscus, which differs from NLM in morphology and histology. Morphologically, it is abnormally widening and covers a larger area of the lateral tibial plateau, with a disc-like appearance and a potential peripheral rim instability. Histologically, the circular collagen fiber is sparse and disordered, and the proportion and distribution of cells are also abnormal.

#### **Agree 36/36, 100%**

There are many kinds of congenital variations for the lateral meniscus, including DLM, Wrisberg meniscus, ring-shaped meniscus, layered meniscus, meniscus defects, meniscus separation, etc., among which the most common type is DLM, and the other variants are rare.<sup>7,38–41</sup> Morphologically,

DLM is broader, the coverage area of the lateral tibial plateau is more than 70%, and the incidence of peripheral rim instability is higher (38%–88%).<sup>1,3,9,42–44</sup> Histologically, the circular collagen fiber of DLM is sparse and disordered in arrangement, and the proportion and distribution of cells differ from NLM<sup>3,10–16</sup> (Grade E).

### *The Wrisberg Meniscus and Ring-Shaped Meniscus Are Different from DLM*

The Wrisberg meniscus and ring-shaped meniscus are not broad and disc-like in shape, and they are different from DLM in clinical characteristics and histopathology. Thus, it is not proper to classify them as DLM but proper to independent variants.

#### **Agree 35/36, 97.2%**

Watanabe et al.<sup>45</sup> classified DLM into complete DLM, incomplete DLM, and Wrisberg meniscus based on the morphology and peripheral rim stability of the lateral meniscus. Monllau et al.<sup>46</sup> recognized ring-shaped lateral meniscus as the fourth type of DLM. However, DLM is unique in anatomy, morphology, and histopathology.<sup>47</sup> Between complete DLM and incomplete DLM, the histological structure is similar, and the differences are mainly reflected in the coverage of the lateral tibial plateau and the thickness of their central region and free rim.<sup>15,48</sup> The Wrisberg meniscus is similar to NLM in morphology and histology, with an incidence of only 0.2%.<sup>41</sup> The ring-shaped lateral meniscus is hollow, without meniscus tissue in the central region, the incidence of which is 0.3–2.4%.<sup>49,50</sup> Given the morphology of these variants is not only significantly different from DLM, but the histopathological features, clinical features, diagnosis, and treatment of those also vary from DLM,<sup>11,13,14,38,51</sup> Wrisberg meniscus and ring-shaped meniscus should not be considered as subtypes of the DLM but as independent variants of the lateral meniscus<sup>52</sup> (Grade C).

### *Epidemiology of Symptomatic DLM*

The incidence of symptomatic DLM varies by race and gender. The Asian population is higher than the Western population, and the female is higher than the male.

#### **Agree 36/36, 100%**

The exact prevalence of DLM worldwide is unclear, which is difficult to estimate because some patients with DLM can remain asymptomatic throughout life.<sup>53</sup> Screening the healthy Japanese population by magnetic resonance imaging (MRI), Futuka et al.<sup>54</sup> found that the prevalence of asymptomatic DLM was 13%. The incidence of symptomatic DLM varies by race and gender,<sup>53,55–57</sup> the Japanese, Korean, Indian, European, and American incidence is 16.6%,<sup>58</sup> 10.5%,<sup>59</sup> 5.8%,<sup>60</sup> and 0.4–5%,<sup>53</sup> and the female (69.6%) is more than twice that of the male (30.4%)<sup>23</sup> incidence (Grade B2).

### *Etiology and Pathogenesis of DLM*

The etiology and pathogenesis of DLM are still unclear. There are several hypotheses, including the hypothesis of

congenital development arrest, acquired hypothesis, genetic hypothesis, etc., but none can independently and accurately explain the pathogenesis of DLM.

**Agree 36/36, 100%.**

The etiology and pathogenesis of DLM are still unclear. Different etiological hypotheses have been put forward, but they cannot properly explain the pathogenesis of DLM.<sup>8</sup> Smillie et al.<sup>61</sup> put forward the hypothesis of congenital development arrest, believing that the meniscus is disc-shaped in the early embryonic stage and its central region is gradually absorbed and transformed into the shape of the normal meniscus with the development of the meniscus. If the development process is halted due to some factors, the discoid meniscus will be formed. However, this hypothesis lacks convincing evidence in embryology and anatomy because discoid meniscus is not found in many embryonic specimens.<sup>62,63</sup> Kaplan et al.<sup>62</sup> proposed the acquired hypothesis. It is believed that the meniscus-tibial ligament of the lateral meniscus was abnormal or absent, which made the link among the posterior horn, the tibia, and the joint capsule loose and the movement range of the meniscus increased with it, in turn leading to the repeated impingement and thickening in posterior horn, and ultimately resulted in the formation of DLM. Nonetheless, this hypothesis cannot reasonably explain the formation of complete DLM or incomplete DLM with normal meniscus-tibial ligament and without high mobility and repeated impingement.<sup>8</sup> DLM was reported to have the family aggregation<sup>16,57,64–66</sup> and was found to complicate with achondroplasia,<sup>67–70</sup> Turner syndrome,<sup>71</sup> and anterior cruciate ligament hypoplasia,<sup>72</sup> which leads to speculation that DLM may be a congenital genetic disease of meniscus dysplasia. However, these results are still in the preliminary exploration stage, lacking studies on the specific molecular mechanism and functional verification. (Grade E).

*Reasons Prone to Lesions and Degeneration of DLM*

DLM features a broad shape, abnormal mechanical stress dispersion, potential instability of peripheral rim, sparse and disorganized circular collagen fiber and nutrient vessels. Moreover, the squeeze and grind between the tibiofemoral joint and DLM can result in mucoid degeneration and lamination in the central area. These characteristics of DLM may be the main reason for more accessibility to degeneration, lesions and retear, and poor healing.

**Agree 36/36, 100%.**

DLM is more prone to lesions and degeneration than NLM.<sup>73,74</sup> Some studies have shown that DLM is broad and almost filled in the lateral compartment of the tibiofemoral joint, which lets DLM not corresponding move in time in the knee flexion, extension and rotation, then leading to longitudinal or complex tears.<sup>75–77</sup> Besides, the peripheral rim of DLM is often loose and unstable, which is easily trapped in the space of the tibiofemoral joint during flexion and extension.<sup>42–44,78,79</sup> In addition, DLM is often complicated with lateral femoral condyle dysplasia and abnormal lower

limb axial alignment, which makes the compressive stress often concentrated in a part of the meniscus and articular cartilage, leading to local lesion or degeneration.<sup>20,80,81</sup> Except for the morphological and anatomical abnormalities above, the circular collagen fibers are disintegrated and disorganized, the nutrient vessels are sparse, and mucoid degeneration often occurs. These pathological characteristics changes may be the main reason DLM is prone to lesions, degeneration, postoperative retear, and poor healing<sup>1,3,9–16,82,83</sup> (Grade E).

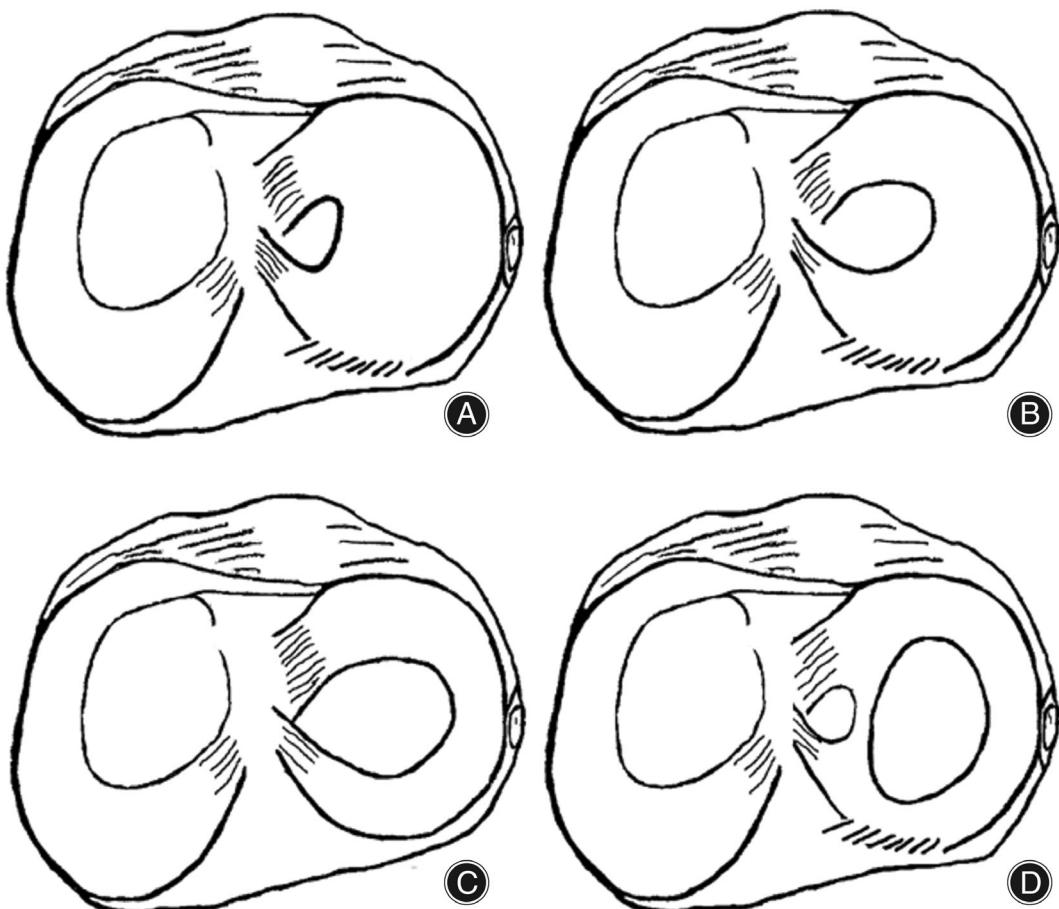
*Classification System of DLM and its Lesions*

According to the morphology and peripheral rim stability, Watanabe classification divides DLM into complete type, incomplete type, and Wrisberg variant meniscus, which is simple and widely used but of less value for treatment planning and prognosis prediction. Based on the morphology, peripheral rim stability, and unstable location, Good classification first divides DLM into complete and incomplete types, then into stable and unstable types, and finally into anterior horn instability, posterior horn instability and instability in both anterior and posterior horn, which is gradually accepted and may be of more guiding value in clinical practice. Classification of DLM lesions and lesion location can refer to the DLM or NLM lesions classification system.

**Agree 36/36, 100%.**

There are many DLM classification systems. Smillie<sup>61</sup> divide DLM into primitive, intermediate, and naive types. Wrisberg meniscus is first described by Kaplan,<sup>62</sup> which then becomes a member of the Watanabe classification system, coordinating with complete DLM and incomplete DLM.<sup>45</sup> Monllau et al.<sup>46</sup> believed that the ring-shaped meniscus could be considered the fourth type of DLM, and forming modified Watanabe classification system (Figure 2). In terms of such variants of the lateral meniscus as Wrisberg meniscus, ring-shaped meniscus, etc., they are similar to NLM but different from DLM in histology,<sup>11,13,14,38,51</sup> and they are not broad in morphology. Therefore, they should not be classified as subtypes of DLM but as other variations of the meniscus.<sup>51,52</sup>

Klingele et al.<sup>30</sup> found incomplete type and complete type account for 37.9% and 62.1% of DLM, and 28.1% of DLM had peripheral rim instability: 47.2% at the anterior third, 11.1% at the middle third, and 38.9% at the posterior third. Subsequently, Good et al.<sup>42</sup> found that the incidence of peripheral rim instability was about 77%, in which the unstable incidence of anterior horn, posterior horn, and both anterior and posterior horn were 53%, 16%, and 6%, respectively. Hence, DLM was first divided into complete and incomplete types and then stable and unstable. The unstable type was further divided into anterior horn instability and posterior horn instability. Based on the Good classification system, Yang et al.<sup>31</sup> classified discoid meniscus into the stable type and unstable type according to its stability, then divided them into the complete type and incomplete type according to their morphology, and further divided them into non-tear, central tear, and peripheral rim tear according to their tear location. Moreover, Lee et al.<sup>32</sup> divided the DLM



**Fig 2** Modified Watanabe classification for discoid lateral meniscus. (A) The complete type is the disc-shaped meniscus that completely covers the lateral tibial plateau and has a normal posterior attachment. (B) The incomplete type has a semilunar shape and normal posterior attachment, but it incompletely covers the lateral tibial plateau. (C) The Wrisberg type is more normally shaped compared to the complete type (A) or incomplete type (B), but it lacks the usual posterior meniscal attachments, and only the Wrisberg ligament connects the posterior horn of the lateral meniscus. (D) The ring-shaped meniscus is characterized by that peripheral attachment with both anterior and posterior horns connected by an inter-horn meniscal bridge.

into the complete type and incomplete type according to its width; into the normal type and hypertrophic type according to the thickness of the free rim; into anterior horn instability, posterior horn instability, and instability in both anterior and posterior horn according to peripheral rim stability; and into no tear or central tear, the horizontal tear in the anterior horn, posterior horn, and both anterior and posterior horn, degeneration, complex, radial tear in the anterior horn, posterior horn, and both anterior and posterior horn according to the type and location of tears. These classification systems emphasized the stability of the peripheral rim and the DLM lesion's location and type have guiding significance on treatment and prognosis.

According to the modified O'Connor meniscus tear classification system, DLM tear was divided into six types: simple horizontal tear, combined horizontal tear, longitudinal tear, radial tear, complex tear, and central tear.<sup>84</sup> Bin et al.<sup>85</sup> divided the DLM tear into six types, namely simple

horizontal tear, complex horizontal tear, longitudinal tear, radial tear, degenerative tear, and complex tear, and found that simple horizontal tear only occurred in complete DLM, while radial, degenerative, and complex tears only occurred in incomplete DLM. In addition, Hamada et al.<sup>86</sup> also reported a kind of symptomatic DLM with an intact shape, without tears on the exterior, but with tears on the interior. The tear location of DLM is similar to NLM, the classification of which can refer to NLM tear location classification system.<sup>87</sup> These tear classification systems are all based on the normal meniscus's various tear classification systems, combined with the tear characteristics of DLM, which have reference values for clinical treatment (Grade B2).

#### *Diagnosis of DLM and its Classification and Lesions*

**The Main Methods of Diagnosing DLM and its Classification and Lesions.** The diagnosis of DLM and its lesions is mainly based on history, clinical manifestations, physical examination,

and imaging examination, and the definite diagnosis method depends on intraoperative arthroscopy.

**Agree 36/36, 100%.**

The history of DLM lesions is most nonspecific. Patients with DLM may experience knee joint symptoms without obvious causes, after mild trauma, or after weight-bearing flexion and rotation of the knee.<sup>4</sup> Moreover, the clinical symptoms may vary depending on morphology, peripheral rim stability, lesion type and lesion location of DLM.<sup>8</sup> Most DLM patients without lesions or with peripheral rim stability did not have clinical manifestations with occasional patients presenting with snapping. Some patients with DLM lesions have obscure symptoms, and most patients' symptoms are similar to the lesion of NLM, such as pain, swelling, locking, weakness, etc.<sup>94</sup> The methods and signs of physical examination of DLM are similar to those of NLM lesions. Some DLM patients may have knee swelling, lateral joint line tenderness, positive McMurray and Thessaly tests, etc.<sup>88–90</sup> Arthroscopy is considered the gold standard in diagnosing meniscus lesions because it can directly observe the shape and integrity of the lateral meniscus and explore the stability and tears of the peripheral rim.<sup>91–94</sup> Mucoid degeneration of DLM shown by MRI cannot directly be observed in arthroscopy but can discover in partial meniscectomy<sup>86,95</sup> (Grade A2).

**Diagnostic Value of History, Symptoms, and Signs on DLM and its Lesions.** Medical history is not specific for the diagnosis of DLM and its lesions. Patients without DLM lesions may have no apparent symptoms or only popping or snapping. Patients with DLM lesions generally have no or only a history of mild trauma, and the symptoms are intermittent and vague, insidious onset, and slow progression. The symptoms and signs of patients with DLM lesions are like those of NLM lesions.

**Agree 36/36, 100%.**

For patients without DLM lesions or instability, the majority may not have clinical manifestations, and a few have popping or snapping.<sup>96</sup> Patients with DLM lesions generally have no apparent history of trauma, and the symptoms are intermittent and vague, insidious onset and slow progression.<sup>4</sup> After DLM lesions, some patients have no clinical symptoms for a long time, and children can only present slightly limited extension.<sup>3,9,47</sup> The typical clinical manifestations of DLM lesions or DLM instability are similar to those of NLM lesions, including such symptoms as pain, popping or snapping, swelling, locking, giving away, lameness, and limited flexion or extension,<sup>3,47,88,97,98</sup> and such signs as effusion, anterolateral bulge at full flexion, quadriceps atrophy, joint line tenderness, limited extension, and positive McMurray test and Thessaly test.<sup>88–90</sup> The accuracy of history, symptoms, and signs in the diagnosis of DLM ranges from 29% to 93%, depending on the doctor's experience<sup>8</sup> (Grade B2).

**Diagnostic Value of MRI on DLM and its Classification and Lesions.** MRI is the preferred imaging method for diagnosing DLM and its lesions, with higher diagnostic accuracy. For unilateral symptomatic DLM, MRI should be recommended for the contralateral knee with asymptomatic or mild symptoms to determine whether the contralateral knee is DLM or combined with DLM lesions.

**Agree 35/36, 97.2%.**

MRI is the most common imaging method for diagnosing DLM and its lesions.<sup>99</sup> The MRI-specific diagnostic criterion of DLM is as follows: (1) the narrowest width of the midsegment of the meniscus on the coronal slice  $\geq 15\text{mm}$ ; (2) the ratio of the minimum meniscal width to the maximum tibial width on the coronal slice  $\geq 20\%$ ; (3) the ratio of the sum of the width of the anterior and posterior horns to the meniscal diameter on the sagittal slice showing the maximal meniscal diameter  $\geq 75\%$ ; (4) the number of consecutive sagittal slices showing continuity between the anterior and posterior horns of the meniscus  $\geq 3$ . The sensitivity and specificity of this criterion are 95% and 97%, respectively.<sup>100,101</sup> In addition, MRI has a certain diagnostic value in classification, tear type and location, and peripheral rim stability of DLM.<sup>48,95,102–107</sup> The diagnostic specificity and sensitivity of MRI in adult DLM tears are 100% and 97.8%,<sup>108</sup> but in children's DLM and its lesions are still controversial.<sup>47,109,110</sup>

In patients with unilateral symptomatic DLM, the probability of DLM in the contralateral knee is about 73%–97%,<sup>6</sup> and of the same type in both is 88%.<sup>6,111,112</sup> Therefore, MRI should be recommended for the contralateral knee to confirm whether it is DLM or discover the obscure lesion<sup>6,47,113,114</sup> (Grade B1).

**Diagnostic Value of Ultrasonography on DLM and its Lesions.** Ultrasonography has high diagnostic accuracy in the morphology and lesions of the lateral meniscus. It can be used for health screening and preliminary diagnosis of DLM and its lesions, especially benefiting patients with emergency and MRI contraindications.

**Agree 36/36, 100%.**

Ultrasonography has unique advantages and high application value in diagnosing musculoskeletal diseases, especially for meniscus tears,<sup>115,116</sup> but diagnosing DLM and its lesions is still in the exploration stage.<sup>117</sup> Achour et al.<sup>118</sup> found sonographic features of DLM in children: (1) the absence of a normal triangular shape; (2) an abnormally elongated and thick meniscus; (3) a heterogeneous central pattern. However, this qualitative description is more subjective and influenced by the examiner's experience. By an Intracavitary Conventional Array Probe or a Linear Array Probe, assessing quantitatively the morphology of lateral meniscus is reliable, noninvasive, convenient, and cost-effective for diagnosing or screening DLM in children.<sup>119</sup> Yang et al.<sup>120</sup> proposed the ultrasonic quantitative diagnostic criteria for DLM based on the angle formed by the upper

and lower arc-shaped surface of the meniscus at the free rim. The cut-off value of the anterior horn angle, body angle, and posterior horn angle in diagnosing DLM were  $28.45^\circ$ ,  $27.85^\circ$ , and  $29.15^\circ$ , respectively. If any parameter is positive, the sensitivity and specificity are 97.8% and 88.9%, used for screening DLM. If all three parameters were positive, the specificity and sensitivity were 98.9% and 76.7%, used for confirming DLM. This ultrasound quantitative diagnostic criterion is of great value for diagnosing DLM in children and other special populations with installed pacemakers, magnetic metal implanted, and claustrophobia<sup>121</sup> (Grade B2).

*Diagnostic Value of X-Ray on DLM and its Classification.* Knee radiographs can be used as an indicative diagnostic method for DLM and its morphological classification by recognizing the unique signs of the knee bone structure. Standing full-length X-rays of lower limbs can provide a reference for the treatment and prognosis of DLM by evaluating lower limb axial alignment.

**Agree 36/36, 100%.**

DLM patients have abnormal development in the knee bone structure, especially in the femoral condyle and tibial plateau.<sup>122</sup> By comparing the parameters of the knee bone structure between DLM and NLM, such as the height of the fibular head, lateral joint space, obliquity of the lateral tibial plateau, or the condylar cut-off sign, etc., it is feasible for X-ray to diagnose DLM and its morphological classification.<sup>19,123</sup> However, the cut-off value, sensitivity (53.8%–87.3%), and specificity (50.0%–90.0%) of the same parameters in the diagnosis of DLM and its morphological classification were inconsistent in various studies.<sup>17–19,123–129</sup>

There is controversy on the relation between isolated tears of DLM and changes in lower limb axial alignment.<sup>20,81,130</sup> However, the varus deformity is common in DLM patients, which can be significantly improved or changed into valgus deformity after arthroscopic meniscectomy, especially in patients with DLM tears and in those who older than 19 years.<sup>20,131</sup> Therefore, the progression of lower limb axial alignment and articular cartilage degeneration in DLM patients should be carefully monitored.<sup>20,131</sup> Evaluation and correction of lower limb axial alignment, individualized treatment, and prevention of articular cartilage degeneration are significant in improving the clinical efficacy and knee function of DLM<sup>21</sup> (Grade B1).

*Major Factors to be Considered in the Treatment of DLM and its Lesions*

Many factors need to be considered in formulating the treatment plan for DLM, including symptoms, signs, age of patients, DLM classification, types, and location of DLM lesions, knee stability, lower limb axial alignment, quality of articular cartilage, sports demand, etc.

**Agree 36/36, 100%.**

Clinical manifestations of DLM and its severity directly affect the choice of treatment options.<sup>3,47</sup> With age, the

incidence of osteoarthritis increases, and the long-term clinical efficacy after surgery decreases.<sup>26,27,131–135</sup> The peripheral rim stability of DLM has an important influence on the treatment plan for symptomatic DLM. DLM with peripheral rim stability usually needs partial meniscectomy, while DLM with peripheral rim instability needs repair or subtotal meniscectomy.<sup>31,136</sup> In general, partial meniscectomy with repair are suitable for simple longitudinal tears in the peripheral rim or red-red zone, whereas radial tears, horizontal tears, oblique tears, and variant tears often require partial or subtotal meniscectomy.<sup>22,29,47,137–140</sup> Knee instability can damage the meniscus or cartilage and lead to a series of knee symptoms. Therefore, restoring knee stability is the basis for achieving good clinical efficacy.<sup>141,142</sup> The severity of articular cartilage lesions or degeneration affects the clinical effect of DLM.<sup>143–148</sup> Arthroscopic surgery is not recommended for treating meniscus lesions with osteoarthritis, but whether arthroscopic surgery should be used for DLM lesions with osteoarthritis has not been determined.<sup>149,150</sup> For DLM patients with abnormal lower limb axial alignment, individualized treatment should be adopted to restore the lower limb axial alignment and reduce articular cartilage lesions and degeneration.<sup>20,21,81,131</sup> In addition, patients' sports demand also affect treatment options. For younger patients with higher sports demand, partial meniscectomy with repair should be adopted as far as possible. For older patients with lower sports demand, total meniscectomy can be considered if conservative treatment fails<sup>28,133,151,152</sup> (Grade C).

*Indications for Conservative Treatment of DLM and its Lesions*

Indications for conservative treatment of DLM and its lesions: (1) asymptomatic DLM; (2) the mild clinical manifestations without obvious effect on daily life and general sports; (3) the severe clinical manifestations caused by such combined disease as osteoarthritis, rheumatoid arthritis, etc.

**Agree 36/36, 100%.**

Stable and intact DLM are most asymptomatic, whether it should be undergone prophylactic surgery and whether prophylactic surgery can reduce the retear rate and improve the knee function are controversial.<sup>56,153</sup> The clinical efficacy of partial meniscectomy for intact DLM is better than for DLM with tears.<sup>154,155</sup> However, for asymptomatic DLM, the knee has adapted to the anatomical shape of DLM, surgical treatment is not recommended, and physical therapy and prevention of overload sports should be recommended.<sup>1,3–5,9,156</sup> DLM patients with mild clinical manifestations, normal lower limb axial alignment, and without articular cartilage lesions should be followed up in the long term.<sup>47,157,158</sup> For DLM lesions combined with osteoarthritis, rheumatoid arthritis, etc., it is necessary to determine the cause of symptoms based on the history, clinical manifestation, and auxiliary examination. For symptoms caused by DLM and its lesions, arthroscopic surgery is a priority selection. For symptoms caused by combined diseases,

arthroscopic surgery should not be first chosen but should actively treat the combined disease<sup>159–162</sup> (Grade E).

#### *Indications for Arthroscopic Surgery of DLM and its Lesions*

Indications for arthroscopic surgery of DLM and its lesions: (1) DLM, DLM lesions, or DLM instability with severe clinical manifestations and a great impact on the patient's daily life and general sports; (2) DLM, DLM lesions, or DLM instability with mild clinical manifestations, and negligible influence on the patient's daily life and general sports, but patient's age is younger.

**Agree 36/36, 100%.**

DLM patients with knee pain, snapping, locking, and limited extension are usually caused by DLM tears or peripheral rim instability.<sup>1,3–5,9,47,156</sup> For patients with peripheral rim stability and without DLM tear, follow-up usually needs if the symptoms are mild; and arthroscopic surgery if the symptoms are severe and continued.<sup>4</sup> For symptomatic DLM patients with peripheral rim instability or DLM tear, arthroscopic surgery should be a priority.<sup>20,26,81,131,132,134,135,143</sup> The blood supply in the peripheral rim of DLM in adolescents and children is abundant, and the long-term clinical effect is excellent and the progression of cartilage degeneration is slow on conditions that the duration of symptoms is short and surgical intervention is early. For adolescents and children with DLM, the blood supply in the peripheral rim of DLM is abundant. If the duration of symptoms is short and surgical intervention is early, the long-term clinical effect is excellent and the progression of cartilage degeneration is slow.<sup>17–19,123–129</sup> In addition, the failure rate of conservative treatment of DLM lesions in children is as high as 39%.<sup>134</sup> Therefore, for adolescents and children with peripheral rim instability or DLM lesions, even if the symptoms are slight and daily life and sports are less impacted, early surgical intervention is needed<sup>7,26,27,47,134,135,138,143,155,163,164</sup> (Grade B2).

#### *Methods and Choices of Surgical Treatment of DLM and its Lesions*

Arthroscopic surgery is the preferred surgical treatment of symptomatic DLM, which mainly includes partial meniscectomy (such as saucerization, meniscoplasty, or reshaping), partial meniscectomy with repair, subtotal or total meniscectomy, and meniscal allograft transplantation. The choice of surgical methods should be comprehensively determined according to the age of patients, DLM classification, types and location of DLM lesions, knee stability, lower limb axial alignment, quality of articular cartilage, sports demand, etc. Partial meniscectomy with or without repair should be performed, when possible, to retain stable remnant meniscus with appropriate width and thickness. Meniscal allograft transplantation can be used for young patients with DLM damage and higher sports demand.

**Agree 36/36, 100%.**

At present, arthroscopic surgery is the primary method for treating symptomatic DLM, which mainly includes

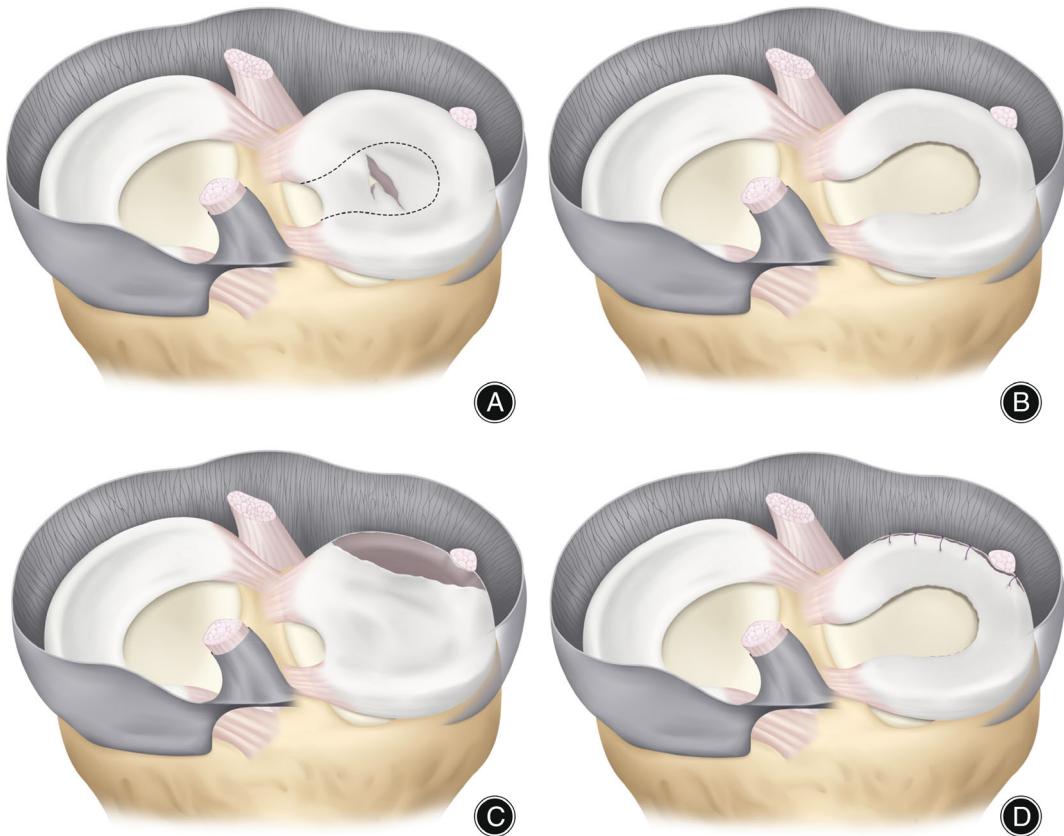
partial meniscectomy, partial meniscectomy and suture/repair Figure 3, subtotal or total meniscectomy, and meniscal allograft transplantation.<sup>1,132</sup> Although there are some differences in the description of the partial meniscectomy of DLM in different literature, such as saucerization, meniscoplasty, or reshaping, all of them resect the redundant central region, retain appropriate width and thickness (usually the width is 6–10mm<sup>165–168</sup>), and finally make the morphology of the remnant meniscus similar to that of NLM.<sup>56,132,143</sup> Partial meniscectomy is currently favored as the treatment for patients with symptomatic stable DLM.<sup>4</sup> For DLM lesions with unstable peripheral rim or suitable for repair, partial meniscectomy with repair is often performed to close the tear, retain the meniscus tissue, and restore the stability of the remnant meniscus.<sup>137,138</sup> Subtotal or total meniscectomy is used for severe degeneration or peripheral rim tear that cannot be repaired. After subtotal or total meniscectomy, the circumferential circular fiber of the remnant meniscus is not continuous, the function of dispersing circular stress is wholly lost, and finally only a tiny amount of non-functional meniscus tissue is left.<sup>5,132,143</sup> Meniscal allograft transplantation is suitable for young patients with DLM damage and higher sports demand, to alleviate knee pain symptoms and improve knee function in patients without menisci.<sup>169,170</sup> (Grade B2).

#### *Indications Repairing DLM Lesions and Peripheral Rim Instability*

Indications for the repair of DLM lesions and peripheral rim instability include: (1) adolescents and children with peripheral rim instability or repairable tears in the red-red or red-white zone; (2) the middle-aged and elderly with peripheral rim instability or repairable tears in the red-red or red-white zone and a higher quality of articular cartilage and remnant meniscus.

**Agree 36/36, 100%.**

For symptomatic DLM, arthroscopic surgery retains the appropriate width of the remnant meniscus, restores its stability to relieve the knee symptoms, and avoids further damage and degeneration of the remnant meniscus and articular cartilage.<sup>1,4</sup> For children with symptomatic DLM, peripheral rim instability or repairable tears in the red-red or red-white zone should be repaired as far as possible to maintain the width and stability of the remnant meniscus.<sup>47,132,164,171</sup> For middle-aged and elderly patients with peripheral rim instability or simple longitudinal tears in the red-red or red-white zone, if the quality of articular cartilage and remnant meniscus is good, partial meniscectomy with repair should be performed as far as possible to retain stable remnant meniscus with the appropriate width and thickness.<sup>1,47,172–177</sup> Subtotal or total meniscectomy should be avoided to alleviate the articular cartilage degeneration<sup>172–177</sup> (Grade C).



**Fig 3** Schematic diagram of partial meniscectomy with or without repair of the discoid lateral meniscus (DLM) under arthroscopy. For DLM with longitudinal tear in the central portion, with stable peripheral rim, and without tear in other parts, the area within the dashed line is the part that needs to be removed in partial meniscectomy (A), and the width and thickness of the remnant meniscus after partial meniscectomy were similar to those of the normal lateral meniscus (B). For DLM with tear in the posterior third of the peripheral rim, with unstable peripheral rim and without tear in other parts (C), the tear in the posterior third of the peripheral rim was sutured and the central portion was resected during partial meniscectomy with repair (D)

#### *Major Factors Affecting the Postoperative Clinical Effect of DLM and its Lesions*

There are many factors affecting the postoperative clinical effect of DLM and its lesions, including gender, age, body mass index, labor intensity, duration of symptoms, peripheral rim stability, DLM type, type and location of DLM lesions, the severity of articular cartilage lesions or degeneration, surgery methods, the width and thickness of remnant meniscus, lower limb axial alignment, knee stability, rehabilitation exercise, etc.

#### **Agree 36/36, 100%.**

The postoperative clinical efficacy of women is generally worse than that of men, which may be related to the thin articular cartilage in women and the abnormal estrogen level in middle-aged and older women.<sup>135,143</sup> Age is the most important factor affecting the postoperative clinical efficacy of DLM. The younger the patients, the more satisfactory the postoperative clinical effect.<sup>26,134,135</sup> Body mass index and labor intensity have similar effects on postoperative clinical efficacy. High BMI and labor intensity usually correspond with poor postoperative clinical efficacy.<sup>143</sup> The

longer the duration of symptoms, the more severe the cartilage lesions or degeneration may be, and the worse the clinical effect will be.<sup>25,35,36,135,143</sup> DLM instability often leads to knee mechanical symptoms. If the stability of the remnant meniscus is not restored, retear often occurs after operation.<sup>31,79,133</sup> After the operation of DLM horizontal or complex tears, the remnant meniscus is often insufficient in width and thickness, which may lead to poor postoperative clinical efficacy.<sup>25,28,178</sup> The central tear generally has no significant effect on the clinical efficacy, but the tears occurring in other locations may affect the postoperative clinical efficacy.<sup>28,179,180</sup> Articular cartilage lesions and degeneration are important factors affecting postoperative efficacy, and the more severe the lesions, the worse the efficacy.<sup>178,181</sup> Generally, total meniscectomy often associates with severe cartilage degeneration and poor long-term clinical efficacy, while partial meniscectomy with or without repair relates to better efficacy.<sup>34,163,177</sup> In addition, if the width and thickness of the remnant meniscus are small, the remnant meniscus is prone to be extruded, the function of the remnant meniscus is poor, and the articular cartilage is more

likely to degenerate. However, if the remnant meniscus is too broad, it is easy to retear.<sup>182-184</sup> DLM is often combined with abnormal lower limb axial alignment. After arthroscopy, the alignment is often changed, and the valgus may occur or aggravate in some patients, leading to cartilage degeneration of the lateral compartment and affecting the postoperative clinical efficacy.<sup>20,21,81,131</sup> Knee instability is an important cause of meniscus or cartilage lesions. Restoring knee stability is the premise of ensuring the treatment effect of DLM.<sup>141,142</sup> A scientific and reasonable rehabilitation exercise is the basis of functional recovery after DLM surgery, which has an important impact on the healing of DLM repair and return to sports<sup>185,186</sup> (Grade C).

#### *Rehabilitation Exercise and Follow-Up of DLM*

Excessive sports should be avoided during conservative treatment. Postoperative rehabilitation programs depend on surgical methods and intraoperative conditions. Generally, full weight-bearing, isometric muscle strength exercises, knee flexion and extension exercises and proprioceptive exercises can be performed early after partial, subtotal or total meniscectomy to restore the stability, balance, and motor function of the knee. After partial meniscectomy with repair, isometric muscle strength exercise can be performed in the early stage, but the full weight-bearing time and immobilization time of the knee should be determined according to the method, quality, and location of repair. DLM patients should be followed up regularly for a long time to observe the status of the remnant meniscus, articular cartilage, and knee joint.

#### **Agree 36/36, 100%.**

Excessive exercise should be avoided during conservative treatment to prevent the aggravation of symptoms or lesions.<sup>1,4,187,188</sup> The development of a rehabilitation plan after arthroscopy should consider the type and location of tears, surgical method, quality of repair, etc.<sup>185,186</sup> After partial or subtotal/total meniscectomy, knee joint activities and isometric muscle strength exercises can be started on the first day, and immobilization with a knee brace is not recommended. Then, fully weight-bearing is feasible in the second week after surgery, continuous active exercise in the fourth week after surgery to restore the knee's proprioception and stability and muscle strength as soon as possible, and recovery of the normal motor in the sixth to the eighth week.<sup>189-194</sup> After DLM repair, recommended rehabilitation protocols vary considerably. Although studies have shown that free rehabilitation exercise after meniscus repair is safe,<sup>195</sup> most scholars think that full weight-bearing time and activity time of the knee should be determined according to the method, quality, and location of repair. After repair surgery, isometric muscle strength exercise can be started on the first day, rehabilitation training with full weight-bearing and proprioceptive training in the fourth to the sixth week, the knee brace can be used to limit knee motion during the first 6 weeks, the range of motion is not limited from the

seventh week, and normal motor can be gradually restored in the 12th to the 16th weeks.<sup>185,189,191-193,196,197</sup> DLM patients should be followed up regularly for a long time to observe the status of the remnant meniscus, articular cartilage, and knee joint<sup>35,151,168,185</sup> (Grade C).

#### **Discussion**

The Chinese expert consensus and practice guideline focused on the definition, epidemiology, etiology, classification, clinical manifestations, diagnosis, treatment, prognosis, and rehabilitation of DLM. Similar to the previous consensus statements on traumatic and degenerative meniscus lesions,<sup>87,198</sup> this consensus states that restoring the normal shape, retaining appropriate width and thickness, and ensuring the stability of the remnant meniscus play critical roles in sustaining the physiological function of the meniscus and preserving the knee.

DLM is the most common congenital variation of the lateral meniscus. There are differences between DLM and NLM both in morphology and histology.<sup>11,13</sup> Morphologically, DLM is broad and disc-like in shape, and its peripheral rim is potential instability.<sup>8</sup> Histologically, the circular collagen fiber of DLM is sparse and arranged in a disorderly manner.<sup>11</sup> Besides, DLM is often combined with knee bone structure dysplasia and abnormal lower limb axial alignment.<sup>1,3,9-21</sup> In addition, the demographic features, pathogenesis, clinical characteristics, diagnosis, treatment, and prognosis of DLM are different from NLM, such as being more common in females, with peripheral rim instability, easy to tear, degeneration and retear after arthroscopy, and lower healing rate and unsatisfactory clinical efficacy in the long term.<sup>22-24</sup> Given these unique features of DLM, the consensus of NLM lesions cannot be directly applied to DLM, and it is necessary to develop a DLM consensus about clinical decision-making and management, which will be conducive to promoting the understanding of DLM and standardizing the diagnosis and treatment process.

The definition of DLM has always been confused. Especially, the phenomenon that the Wrisberg meniscus and ring-shaped meniscus are mistreated as DLM is more likely to misunderstand DLM and is not conducive to standardizing diagnosis and treatment, scientific research, and academic exchanges. There are significant differences between DLM and NLM both in morphology and histology. However, the morphology and histology of the Wrisberg meniscus and the ring-shaped meniscus are similar to NLM.<sup>41,47,49,50</sup> Therefore, it is improper to classify these variants as DLM, which is approved by numerous scholars and proposed some new DLM classification systems excluded Wrisberg meniscus and ring-shaped meniscus.<sup>31,32,42</sup> Good<sup>42</sup> and Lee<sup>32</sup> classification systems can more accurately reflect the actual status of DLM than the Watanabe classification, which is important to understand DLM, formulate surgical planning, and predict prognosis.

The diagnosis of DLM and its lesions has always been the focus of clinical research. The history and clinical manifestations of symptomatic DLM are not specific, and the diagnosis is mainly based on imaging examination.<sup>1,98</sup> As the preferred imaging method, the specificity and sensitivity of MRI in diagnosing DLM and its lesions is higher, but in diagnosing the classification and peripheral rim stability of DLM, important to surgical plan and prognosis prediction, is difficult.<sup>102,104,108,179</sup> The accuracy of ultrasonography in diagnosing meniscus lesions is comparable to that of MRI, but the diagnosis of DLM and its classification and lesions is potential and still in the preliminary exploration stage. The real-time dynamic observation, the unique advantages of ultrasound, may enable it to become a reliable new method for diagnosing DLM and its classification and lesions.<sup>41,118-120,199</sup> In recent years, there are many studies about the diagnosis of X-ray on DLM and its classification, but X-ray can only be used as an indicative diagnostic method because its diagnostic value is influenced by measuring error and the distance between the X-ray tube and knee joint.<sup>17-19,123-129</sup>

The key points of DLM treatment are restoring the normal shape, retaining the appropriate width and thickness, and preserving the remnant meniscus's stability. The significant differences in morphology, peripheral rim stability and tissue structure of meniscus and knee bone morphology between NLM and DLM render DLM more accessible to degeneration, tear, retear after surgery, and poor healing.<sup>3,10-16</sup> Therefore, even though DLM's shape and stability were recovered to normal by surgery, the tissue structure and physiological function of the remnant meniscus are difficult to reach the level of NLM, which brings great challenges to the arthroscopic surgery of DLM. For patients with asymptomatic DLM, this consensus indicates long-term follow-up is suitable for the middle-aged and elderly, and arthroscopic surgical intervention is preferred for adolescents and children with DLM tears and high sports demands. For patients with symptomatic DLM, although total meniscectomy can achieve good mid- and short-term clinical results, the long-term clinical efficacy is dissatisfaction because the cartilage degeneration is at more significant progression than that of partial meniscectomy, especially for adolescents and children.<sup>173,184,192</sup> Therefore, this consensus recommends that stable remnant menisci with high tissue quality and appropriate width should be retained as far as possible, regardless of the patient's age. Partial meniscectomy is a common surgical method preserving the remnant meniscus, but it cannot retain the remnant meniscus for patients with peripheral rim instability or tears in the red-red or red-white zone. In this case, partial meniscectomy with repair offers the possibility to restore stability and preserve the remnant meniscus with appropriate width and thickness.<sup>4,173,197,200</sup> Therefore, this consensus suggests that repair surgery should

be determined based on DLM stability, characteristics of lesions, quality of remnant meniscus, cartilage status, age of the patient, and sports demands.

This consensus has some limitations. Literature about DLM has relatively low scientific quality, which may influence the level of evidence of the consensus. The validation of all statements by the rating and peer review groups was based on the expert's understanding of the current literature and clinical experience. Therefore, this consensus should not be regarded as a guideline for treating DLM and its lesions but as the best recommendation possible. With further studies, the understanding of this topic will expand, and profound insights could be obtained in the future.

### Conclusions

This expert consensus focused on the definition, epidemiology, etiology, classification, clinical manifestations, diagnosis, treatment, prognosis, and rehabilitation of DLM. Endorsed statements in this consensus will help to strengthen the understanding and standardize the diagnosis and treatment of DLM. Restoring the normal shape, retaining appropriate width and thickness and ensuring the stability of the remnant meniscus is critical to sustaining the physiological function of the meniscus and preserving the knee. The partial meniscectomy with or without repair should be the first-line treatment when possible, given that the clinical and radiological long-term outcomes of total or subtotal meniscectomy are worse.

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### Disclosure

**A**ll authors declare no conflicts of interest.

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