



Posterior Horn Repair Augmented With the Central Portion of Thickened Meniscus for Large Posterolateral Corner Loss Type of Discoid Lateral Meniscus

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Abstract: Large posterolateral corner loss type of discoid lateral meniscus tear is unsalvageable. Therefore, subtotal meniscectomy has been the only treatment option in this case. However, long-term results of subtotal or total meniscectomy have shown a high prevalence of early degenerative changes. Persistent symptoms, such as increased pain, snapping, giving way, locking, and limited extension, can be attributed to progressive loss of posterior tibial meniscal attachment and meniscal degeneration, especially in the posterior horn. The purpose of this technique-based article is to describe a partial repair, posterior horn repair augmented with the central portion of the discoid lateral meniscus that would have been removed if a subtotal meniscectomy were performed and bone marrow stimulation in the intercondylar notch to improve meniscal healing.

Discoid lateral meniscus (DLM) is a not uncommon congenital anomaly of the knee, with a reported incidence rate of 0.4% to 16.6%.^{1,2} Asymptomatic DLMs that are found incidentally require no treatment other than observation. However, DLM is prone to tear even without obvious trauma because of its thickness, poor vascularization, hypermobility, and a weak attachment of the posterior area to the capsule.³

Studying the relationship between tear pattern and type of DLM, Bin et al.⁴ classified DLM tears into tear patterns like in a normal meniscus, such as longitudinal, radial, horizontal, degenerative, and complex.

Ahn et al.⁵ classified the peripheral longitudinal tears of DLM in children into 3 types in detail: (1) meniscocapsular junction, anterior horn type; (2) meniscocapsular junction, posterior horn type; and (3) posterolateral corner (PLC) loss type.⁵ The PLC loss type is a unique tear pattern in DLM and mainly involves the entire posterior horn and midbody. If not treated, it may get larger and larger over time. Therefore, the tear configuration of the PLC loss in adults is usually immense and complex, leaving a scanty, nonfunctional rim. Almost the whole DLM inevitably needs to be resected in a case like that.⁵ However, with understanding of meniscal functions and improvement of the arthroscopic technique, current treatment recommendations prefer meniscal preservation to meniscectomy not only in normal meniscus but also in DLM.⁶

Hence, we present the posterior horn repair augmented with the central portion of the DLM that would have been removed if a subtotal meniscectomy were performed and bone marrow stimulation (BMS) in the intercondylar notch to improve meniscal healing (Video 1).

Surgical Technique

Surgical Approach

The patient is placed supine on the table and receives spinal anesthesia with or without sedation.

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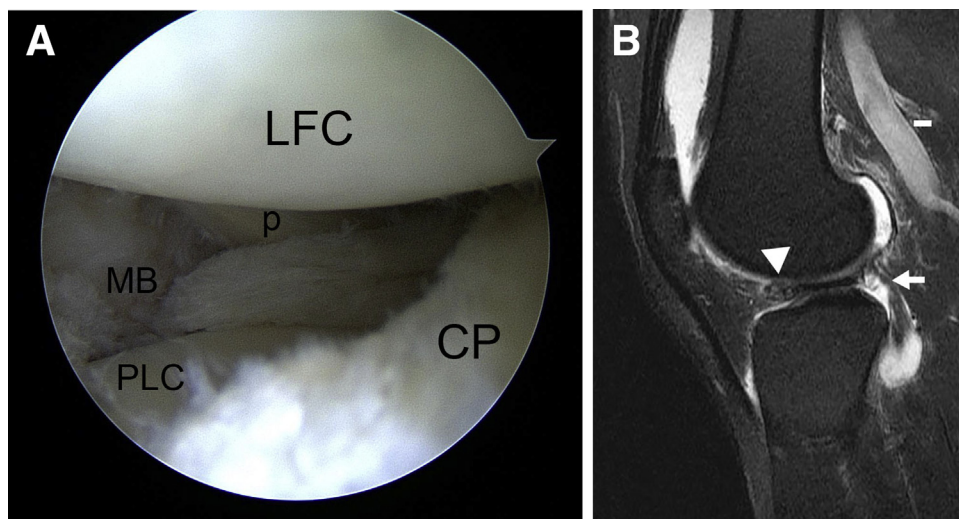


Fig 1. (A) Lateral compartment of right knee viewing from the high anterolateral portal. There is considerable posterolateral corner loss of the discoid meniscus such as a large hole and the radial tear of the midbody. (B) Preoperative sagittal T2 weighted magnetic resonance imaging of the right knee shows a loss of the posterior horn of the DLM (arrow) and cystic anterior horn (triangle). (CP, central portion; LFC, lateral femoral condyle; MB, midbody; P, popliteus; PLC, posterolateral corner.)

After a thigh tourniquet is placed, the knee is prepped and draped in a standard fashion. A high anterolateral (HAL) portal is established, and a 30° arthroscope is then introduced into the joint. While viewing through the HAL portal, a low anteromedial (LAM) portal and a medial patellofemoral axillary (MPFA) portal are created and diagnostic arthroscopy is subsequently performed.⁷ The arthroscope is moved into the joint through the MPFA portal, and a low anterolateral (LAL) portal is established. The HAL and MPFA portals are used as the viewing portals and the LAL, HAL, and MPFA portals are used as the working portals. The lateral compartment is viewed with the lower limb in the figure-of-4 position. The loss of the PLC typically involves the posterior horn and

midbody (Fig 1 A, B). Margins of the tear side are abraded, and the scanty remnant of the posterior horn of the DLM is especially freshened by a motorized shaver (Sabre, 3.0 mm; Arthrex, Naples, FL) to promote healing.

Preplacing a No. 2 Ethibond for the Second Posterior Horn Augmented Repair

Initially, a curved suture hook (Linvatec, Largo, FL) loaded with a No. 1 polydioxanone suture (PDS II; Ethicon, Livingston, UK) is inserted through the LAL portal while viewing from the MPFA portal and penetrates the peripheral scanty rim just posterior to the popliteal hiatus from superior to inferior. The leading limb of the PDS II suture is advanced sufficiently into the

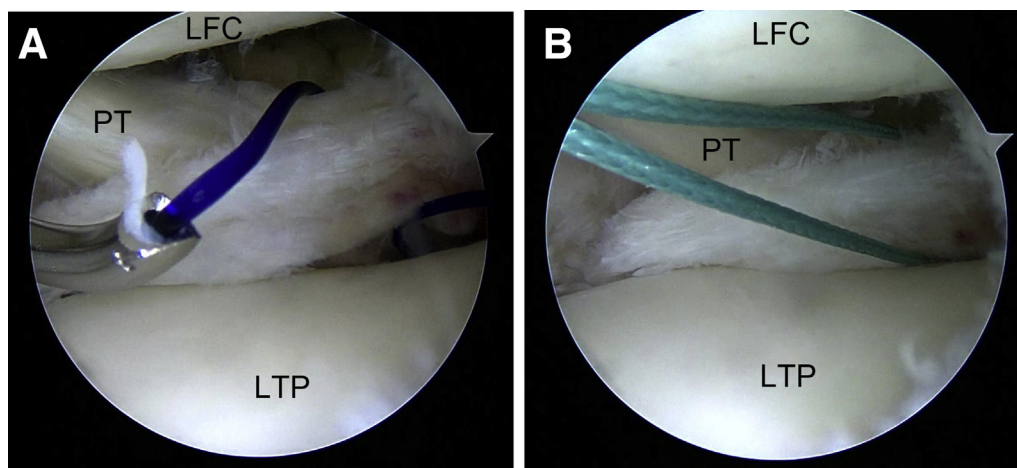


Fig 2. Right knee, lateral compartment. (A) A curved suture hook preloaded with a No. 1 polydioxanone suture (PDS II) is introduced through the low anterolateral portal while viewing from the medial patellofemoral axillary portal and then is passed through the peripheral scanty rim just posterior to the popliteal hiatus from superior to inferior. The leading limb of the PDS II suture is advanced sufficiently into the joint. (B) The PDS II is changed for the Ethibond from the tibial to the femoral surface by the use of the shuttle relay technique. (LFC, lateral femoral condyle; LTP, lateral tibial plateau; PT, popliteus tendon.)

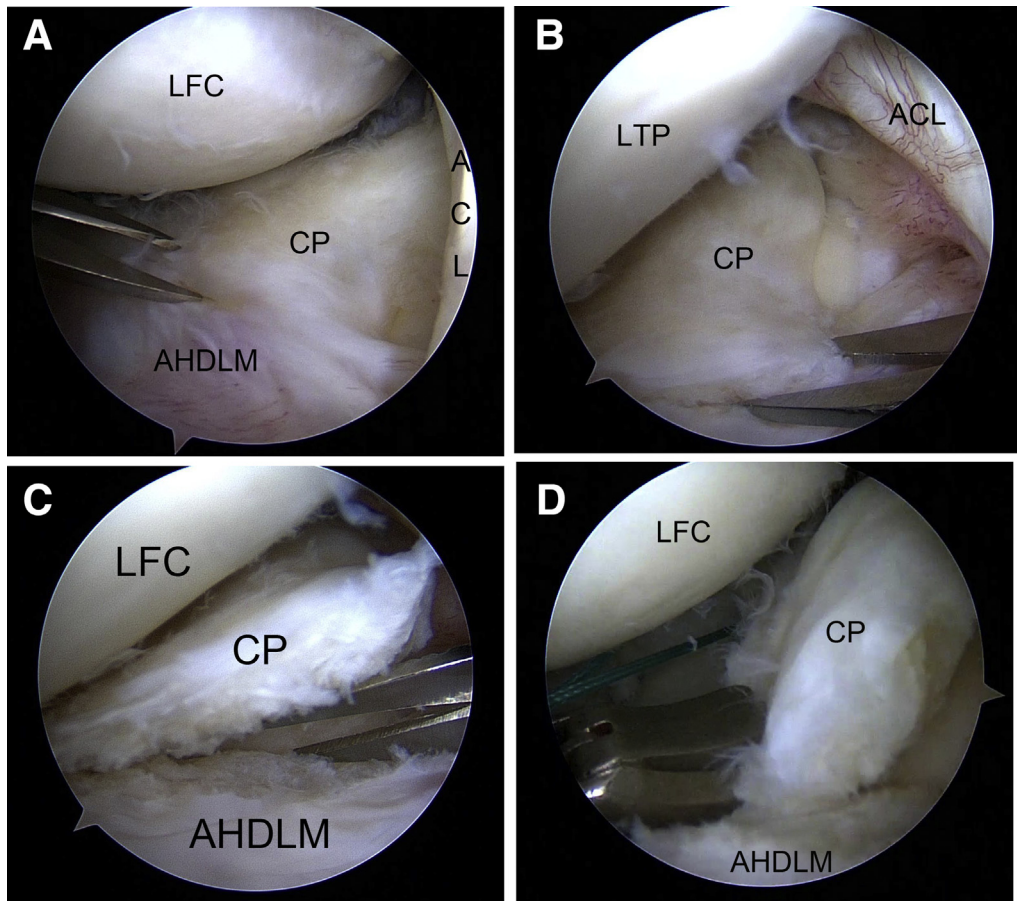


Fig 3. Division at anteromedial corner of remnant discoid lateral meniscus in the right knee. (A) At the junction of the anterior horn and central thick portion, the superior plane of the anterior portion of discoid lateral meniscus is incised with the iris scissors through the high anterolateral portal while viewing from the medial patellofemoral axillary portal. (B, C) With the arthroscope in the high anterolateral portal, the inferior plane cut is made with the scissors through the medial patellofemoral axillary portal. (D) To adjust the meniscal width, the thick inner portion is reshaped by trimming the torn lateral margin with an arthroscopic punch through the low anterolateral portal while viewing from the medial patellofemoral axillary portal. (ACL, anterior cruciate ligament; AHDLM, anterior horn of discoid lateral meniscus; CP, central portion; LFC, lateral femoral condyle.)

joint (Fig 2A). A suture retriever is inserted through the LAL portal, and the leading limb is retrieved. One end of a No. 2 Ethibond (Ethicon, Somerville, NJ) is passed into a loop made at the leading limb of the PDS II, and the suture hook is retrieved and pulled by holding the PDS II. The PDS II is changed for the Ethibond from the tibial to the femoral surface by the use of the shuttle relay technique (Fig 2B). The superior end of the Ethibond suture is marked with a straight hemostat, and the inferior suture end is left unmarked. This technique places the 1-Ethibond stitch on the posterior horn remnant before incising the anterior horn. If preferred, all sutures can be done after cutting it.

Division and Reshaping of the Central Meniscal Portion of DLM

After incising the superior half of the anterior portion of DLM along the borderline between the anterior horn

and central thick portion with a curved iris scissors through the HAL portal (Fig 3A), the inferior half cut is made with the iris scissors through the MPFA portal (Fig 3 B and C). The inner rim of the anterior horn of meniscus is smoothed with a motorized shaver. If an unstable inferior leaf of the anterior flap of the cut central thick portion exists, it should be debrided with a motorized shaver. To adjust the meniscal width, the thick inner portion is reshaped by trimming the torn lateral margin with an arthroscopic punch (Large Punch Straight Jaw; Arthrex; Fig 3D). Using a probe, the central thick portion is repositioned posteriorly to the lost part of the posterior horn. If a dog ear is encountered at the posterior hinged portion, it should be trimmed before repairing the posterior horn, because the central thick portion has a tendency to return to the original position if it is left untouched (Fig 4). From the authors' experience, as more meniscus is lost, the

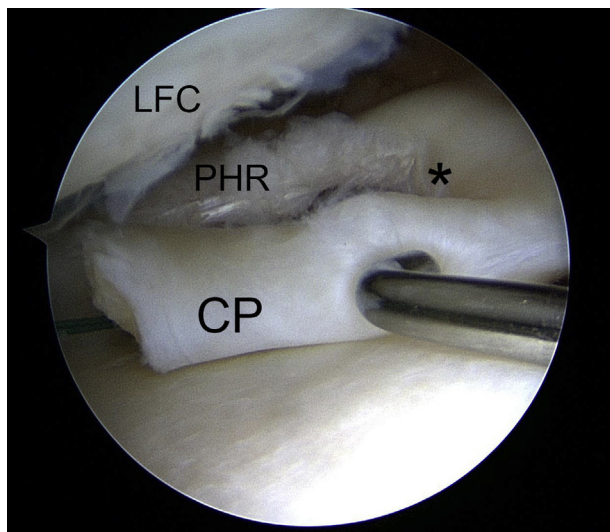


Fig 4. Right knee, disoid lateral meniscus. To make the central portion mobile and reposition the inner thick portion posteriorly, removal of the meniscal tissue at the posterior hinged portion (*) is performed with an arthroscopic punch through the low anterolateral portal while viewing from the medial patellofemoral axillary portal. The arthroscope is moved into the joint through the high anterolateral portal. The mobility of the central thick portion should be checked by a probe through the medial patellofemoral axillary portal. (CP, central portion; LFC, lateral femoral condyle; PHR, posterior horn remnant.)

propensity for formation of dog ear is lessened. Therefore, unacceptable dog ear is rare in the case of an advanced PLC loss type tear of DLM that has significant loss of meniscus.

Posterior Horn Repair Augmented With the Central Portion of Thickened Meniscus

Once the central thick portion has been freed enough to reach the posterior horn, the suture hook preloaded with a No. 1 PDS II suture is introduced through the MPFA portal with the arthroscope in the HAL portal and then is passed through the peripheral rim of the posterior horn from superior to inferior (Fig 5A). The PDS II that is advanced into the joint is changed for the Ethibond in the manner described previously (Fig 5B). The suture hook loaded with a No. 1 PDS II suture is inserted through the MPFA portal once again and then penetrates the central thick portion of remnant meniscus from top to bottom (Fig 5C). The bottom sides of the PDS II and Ethibond sutures are held together and retrieved simultaneously by use of the suture retriever through the MPFA portal. The bottom side end of the Ethibond is tied with the bottom side end of the PDS, and the hemostat holding the superior end of the Ethibond is then pulled. The PDS is passed through both sides of the meniscus tear, and Ethibond is changed into the PDS (Fig 5D). Both ends of the PDS are held together and

retrieved through the MPFA portal, and the PDS II is tied with a sliding knot (Fig 6A). An additional 2 or 3 half-hitch knots with alternating posts on reverse throws are made for knot security. The first suture is placed in close proximity to the root of the posterior horn of DLM. A second suture is made using the previously inserted Ethibond in the same manner and placed anterior to the first (Fig 6 B and C). The radial tear of the meniscal rim of the midbody commonly occurs in the typical PLC loss type, and side-to-side repair is done using all-inside suture with a suture hook (Fig 6D). After suturing, the loop and knot security are evaluated with a probe.

BMS With a Steinmann Pin at the Intercondylar Notch

Meniscal repair is augmented with a BMS because the central thick portion of the DLM has relatively poor vascularity and there is a concern for adequate healing. With the knee in about 60° flexion, an 18-gauge needle is inserted just medial to the distal portion of the patellar tendon and advanced to the intercondylar notch along the anterior edge of the tibial plateau. Once the appropriate location is identified, a stab wound is made with a No. 11 blade, and a nick-and-spread technique is performed using a straight hemostat. Viewing from the HAL portal, a 4.5-mm Steinmann pin is introduced into the joint (Fig 7A), and its tip is placed slightly posterior to the apex of the intercondylar notch (Fig 7B). It is then drilled 5 to 8 cm proximally into the femoral canal with Steinmann pin's axis held at 15° to 20° to the long axis of the femur in the lateral plane (Fig 7C). After tourniquet deflation, marrow contents are observed spilling into the knee joint space (Fig 7D).

Postoperative Care

Immediately after the operation, the knee is immobilized using a cylinder splint in a full extended position, and a limited motion brace is applied after 2 weeks. Knee motion is then instituted, with the goals of achieving 90° knee flexion within 4 weeks. Partial weight bearing is allowed after 6 weeks, and full weight bearing is permitted after 10 to 12 weeks. Squatting is restricted for at least 6 months after repair. Sports activity is also restricted for 10 to 12 months postoperation.

Discussion

In the authors' experience, a relatively high frequency of the PLC loss type occurs in adults with symptomatic complete DLM. Ahn et al.⁸ reported on 329 cases of symptomatic torn DLM in patients older than 20 years. Based on the arthroscopic findings, they classified the tear patterns of the DLM into 5 types: (1) horizontal tear, (2) peripheral tear, (3) peripheral and

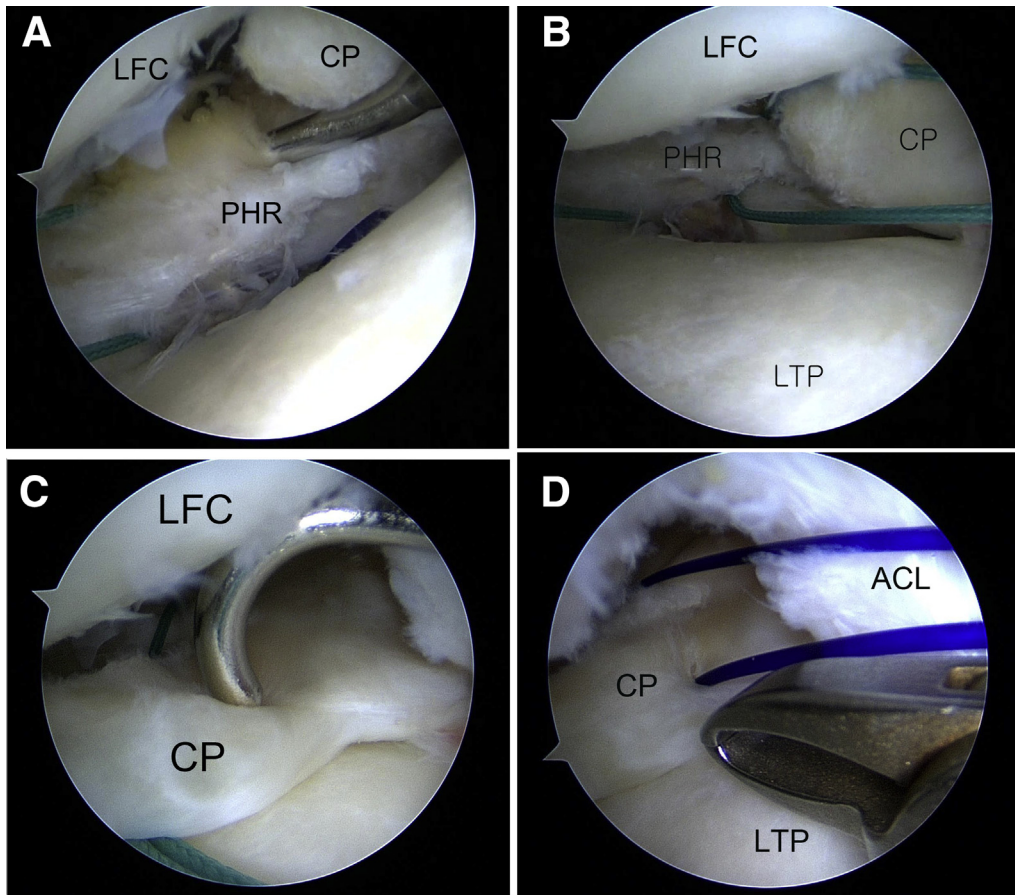


Fig 5. During the suturing of the discoid lateral meniscus of the right knee, the arthroscope is placed in the high anterolateral portal and a curved suture hook is inserted into the medial patellofemoral axillary portal. (A) After the central thick portion is everted posterior to the lateral femoral condyle by the suture hook, it is passed through the peripheral rim close to the root of the posterior horn. (B) The PDS II that is advanced into the joint is changed for the Ethibond. (C) The suture hook loaded with a No. 1 PDS II suture is inserted through the medial patellofemoral axillary portal once again, and then it penetrates the central thick portion of the remnant meniscus from top to bottom. (D) The PDS is passed through both sides of the meniscus tear. (ACL, anterior cruciate ligament; CP, central portion; LFC, lateral femoral condyle; LTP, lateral tibial plateau; PHR, posterior horn remnant.)

horizontal tear, (4) the PLC loss type, and (5) others (transverse tear or marginal degenerative tear, which is difficult to define). Among the 329 knees, the PLC loss tear (29%) was the second most prevalent type after horizontal tear (31%).⁸

Until now, the preferred treatment for large PLC loss type tear of DLM has been subtotal or total meniscectomy. If PLC loss is more than 1 cm, both sides of the tear cannot be approximated. It is inevitable that arthroscopic subtotal meniscectomy along the tear will be performed.⁵ Although there is considerable posterolateral loss of the DLM such as a large hole, the central thick portion of the meniscus, which is displaced to the intercondylar notch, will remain relatively intact. Therefore, the lost part of the meniscus, including the entire posterior horn and a portion of popliteal hiatus,

can be reconstructed by transposing the remaining central fragment. Even in a large to massive tear that appears irreparable, attempting to repair it as much as possible to possibly convert it into a functional meniscal construct by recreating balanced horns (Fig 8) can be helpful in reducing pain as well as improving functional outcomes (Table 1).

According to studies conducted in the early 1990s, the reported rates of clinical success for isolated meniscus tears repaired in ACL stable knees ranged from 50% to 57%.^{9,10} Therefore, for meniscal healing in isolated meniscal tears, a variety of augmentation techniques have been developed, including marrow stimulation, synovial rasping or abrasion, trephination, fibrin clot, platelet-rich plasma, stem cells, and growth factors.¹¹ Meniscal tears in vascular zones have been the ideal

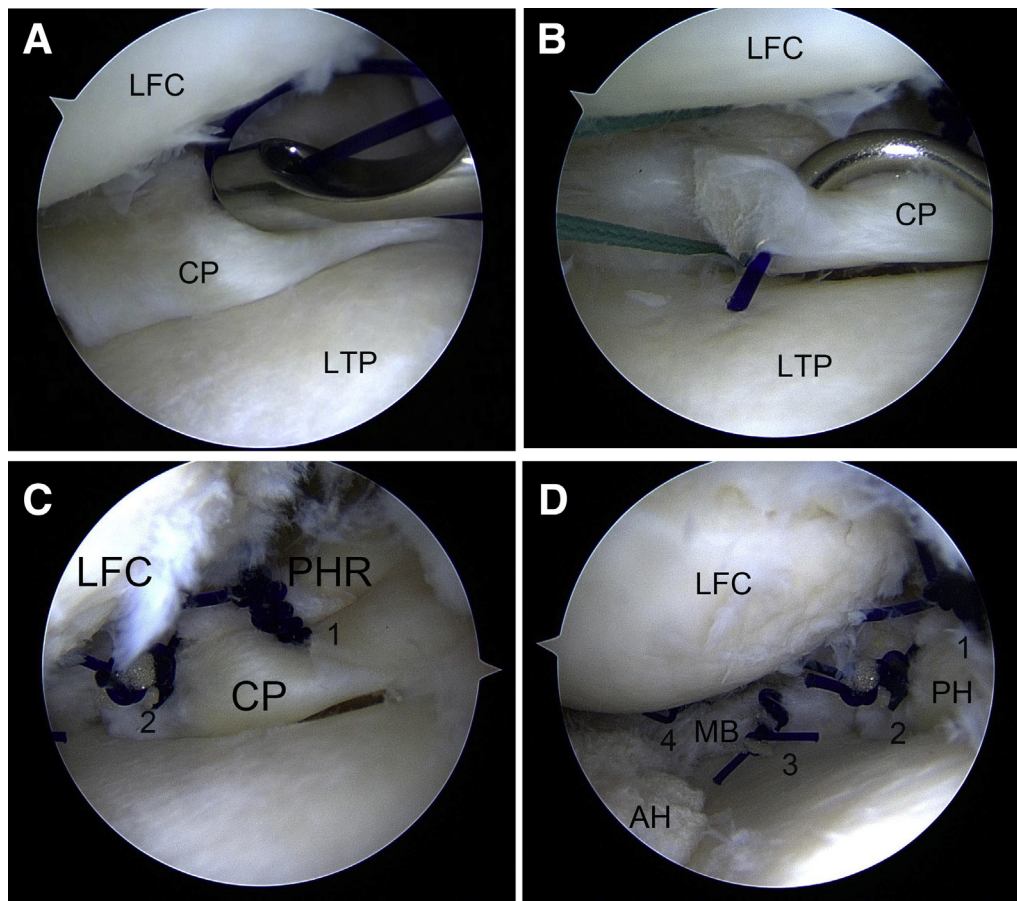


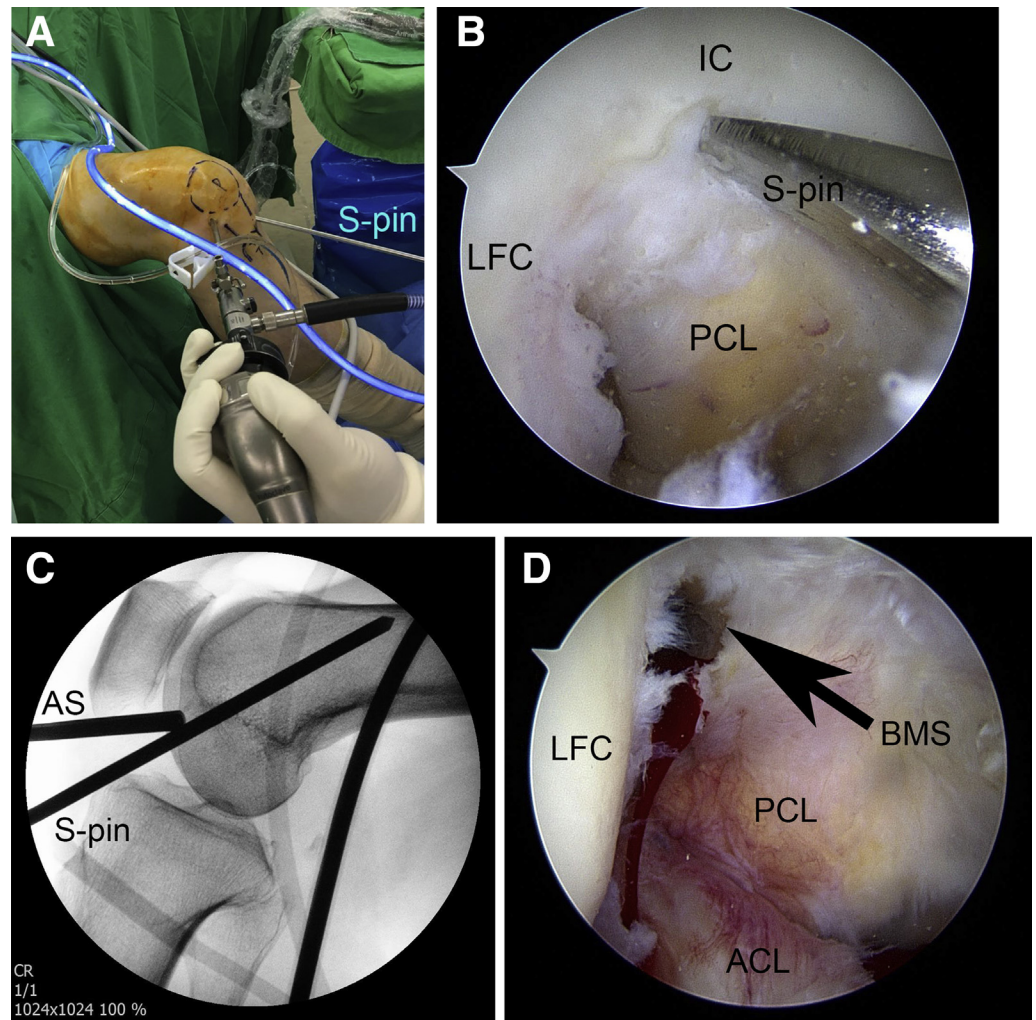
Fig 6. Right knee. (A) Using an arthroscopic knot pusher, the PDS II is tied with a sliding knot while viewing from the high anterolateral portal. An additional 2 or 3 alternating half hitches are used to secure the knots. (B) The suture hook loaded with a No. 1 PDS II suture penetrates the lateral end of the central thick portion. A second suture is made using the previously inserted Ethibond in the same manner. (C) The lost part of the posterior horn is reconstructed by transposing and suturing the reshaped central portion (1, the first suture; 2, the second suture). (D) Final arthroscopic image from the medial patellofemoral axillary viewing portal. Repair for the horizontal tear in the scanty meniscal remnant around popliteal hiatus (3) and the radial tear of the midbody (4) are done using all-inside suture with a suture hook. (AH, anterior horn; CP, central portion; LFC, lateral femoral condyle; LTP, lateral tibial plateau; MB, mid-body; PH, posterior horn; PHR, posterior horn remnant.)

indication for repair. With the introduction of augmentation techniques for meniscal healing, however, indications for meniscal repair can be wide and meniscal repair has recently been tried for tears even in avascular zones,¹² horizontal tears,^{13,14} and more complex tears.¹⁵

We performed a marrow-stimulating technique for augmentation of meniscal healing in large PLC loss type of DLM tear because the central thick portion of the DLM has relatively poor vascularity and there is a concern for adequate healing. Interestingly, meniscal tears repaired in conjunction with anterior cruciate ligament (ACL) reconstruction are more likely to heal, compared with the repair of isolated meniscus tears in ACL stable knees.^{9,10,16} In a matched-cohort population study, Wasserstein et al.¹⁷ reported the rate of meniscal

reoperation to be 9.7% in the cohort that underwent ACL reconstruction and meniscal repair versus a 16.7% reoperation rate in the cohort that underwent meniscal repair alone. Researchers believe that intercondylar notchplasty and bone tunnels made at the time of ACL reconstruction have improved meniscal healing, mainly owing to the release of marrow elements including progenitor cells and growth factors.¹⁸ A 2015 experimental study by de Girolamo et al.¹⁹ reported that the joint fluid concentration of platelet-derived growth factor was significantly higher in patients who underwent ACL reconstruction than in those who underwent arthroscopic partial medial meniscectomy, thus demonstrating the role of platelet-derived growth factor in enhancing the healing response of meniscal suture. The BMS in the femoral intercondylar notch in a rabbit

Fig 7. Bone marrow stimulation procedure in the right knee. (A) A 4.5-mm Steinmann pin is inserted just medial to the distal portion of the patellar tendon, and then (B) it is advanced to the intercondylar notch while viewing from the high anterolateral portal. (C) A C-arm image intensifier shows the Steinmann pin's position and direction in the distal femur. However, we do not routinely check the image intensifier for marrow stimulation procedure. It was performed to help readers understand. (D) After the tourniquet deflation, this results in the spilling of marrow contents into the knee joint. (ACL, anterior cruciate ligament; AS, arthroscope; BMS, bone marrow stimulation hole; IC, intercondylar notch; LFC, lateral femoral condyle; PCL, posterior cruciate ligament; S-pin, Steinmann pin.)



model led to modest improvements in both the quality and quantity of reparative tissue bridging at the site of meniscal defect, particularly during the first several weeks after injury.²⁰ Dean et al.²¹ reported a 12.9% failure rate in meniscal repair performed with biological augmentation using a marrow venting procedure and a 7.8% failure rate in that performed concomitantly with ACL reconstruction, with no significant difference in failures between the cohorts. The similar outcomes found between the 2 cohorts in their study may be partially attributed to the use of biological augmentation.

Based on the concept described previously, BMS with a Steinmann pin at the intercondylar notch in our present technique may be considered one of the factors that are helpful for a high healing rate. Furthermore, compared with the use of exogenous fibrin clot, our marrow stimulation technique is simple, easy, and inexpensive. The marrow stimulation in the intercondylar notch, however, may cause chondral damage. In an animal study, the location of marrow stimulation

(distal femoral chondral surface anterior to the apex of the intercondylar notch) is undesirable, as it injures the distal femoral articular cartilage. Therefore, we modified the starting point of the BMS to not damage the distal femoral chondral surface (Table 2).

However, there are several limitations and risks associated with this technique. First, the scanty meniscal rim of the midbody cannot be reinforced owing to the limited length of the transposed meniscal fragment, and thus this technique is not a complete but a partial repair (Table 1). Therefore, more clinical trials are necessary to investigate the long-term outcomes of our technique. Second, this BMS technique cannot be used for skeletally immature patients (Table 2). Therefore, to avoid injury to the physis of the distal femur, we recommend synovial abrasion, fibrin clot, and marrow stimulation with a microfracture awl at the lateral aspect of the intercondylar notch for these patients. Third, if infected, it may be possible to propagate infection into the bone marrow of the distal femur through the hole of the intercondylar notch (Table 2).



Fig 8. Right knee, lateral compartment. Follow-up sagittal T2 weighted magnetic resonance imaging 3 months after posterior horn repair augmented with central thick meniscal fragment shows relatively good reconstruction of the posterior horn (arrow) and nearly normal anterior horn without cysts (triangle).

However, the risk of infection is the same as that with common arthroscopic meniscus repairs. Fourth, a slipped Steinmann pin may damage the posterior neurovascular structure (Table 2). To avoid this risk, we hope to proceed step by step according to the summarized description of this procedure.

Finally, our technique, posterior horn repair augmented with the central portion of thickened meniscus suggests an alternative treatment option for large PLC loss type of DLM. The BMS technique with a Steinmann pin can be considered an alternative method for the augmentation of meniscal healing. Furthermore, we think that arthroscopic partial repair and posterior horn augmentation are recommended in patients who do not want to undergo lateral meniscus transplantation or in countries where the national public health care funds are limited and lateral meniscus transplantation is not allowed.

Table 1. Advantages, Limitations, Pearls, and Pitfalls of the Posterior Repair Augmented With Central Thick Meniscal Portion

Advantages	Limitations
Torn central meniscus tissue is preserved to reconstruct the posterior horn.	Unfortunately, the scanty meniscal rim of the midbody cannot be reinforced because of the limited length of the transposed meniscal fragment.
All-inside suture technique without neurovascular risk does not require additional incision and dissection.	This technique is not a complete but a partial repair.
This technique is able to reconstruct the posterior horn even in massive PLC loss tear because the inner portion of a DLM remains relatively intact in case of a torn DLM.	
The augmentation repair of posterior horn converts the PLC loss of a DLM tear into a functional meniscal construct by recreating a balanced horn.	
This technique may contribute to restoring hoop tension and preventing accelerated degenerative changes in the knee joint.	

Pearls	Pitfalls
A curved iris scissors rather than a basket forceps is recommended to make the beveled inner margin of the anterior horn and preserve the length of the transposed meniscal portion.	With insufficient trimming or debridement, the hinged portion may result in a dog ear.
Debride meticulously the scanty remnant of the posterior horn of DLM using a motorized shaver to promote meniscal healing.	The tip of a suture hook may damage the articular cartilage when penetrating the central thick meniscal portion.
The radial tear of the meniscal rim of the midbody and chondral lesion in the lateral compartment can be managed concurrently with side-to-side repair using a suture hook and cartilage debridement, abrasion chondroplasty, and microfracture.	
Full-thickness, superior to inferior sutures of central meniscal tissue enable posterior horn repair with a good tissue approximation between the inner portion of the DLM and the remnant rim of the posterior horn.	

DLM, discoid lateral meniscus; PLC, posterolateral corner.

Table 2. Advantages, Disadvantages, Pearls, and Pitfalls of Bone Marrow Stimulation (BMS) in the Intercondylar Notch

Advantages	Disadvantages
BMS with a Steinman pin is a simple and inexpensive technique (ease of access, reproducibility, and direct approach).	This technique cannot be applied for skeletally immature patients.
The release of marrow contents including pluripotent mesenchymal progenitor cells and growth factors stimulates meniscal healing.	If infected, it may be possible to propagate infection into the bone marrow of the distal femur through the hole of the intercondylar notch.
Hemarthrosis in the knee joint may lead to clot formation within the repaired site of the meniscus, providing a scaffold for cellular adhesion and differentiation.	Patients may complain of some discomfort such as persistent swelling and fullness of the knee joint for a while.
BMS just posterior to the apex of intercondylar notch results in no or quite minimal damage to the trochlear articular cartilage.	
Pearls	Pitfalls
To prevent the Steinmann pin from sliding, its axis should be held at 15° to 20° to the long axis of the femur in the lateral plane and drilling should be started slowly.	Malposition of the Steinmann pin's tip could injure articular cartilage on the trochlea of the femur.
To secure the clear view of the tip of a spinal needle, hemostat, and Steinmann pin during BMS procedure with the knee in about 60° flexion, debride the infrapatellar fat pad sufficiently.	A slipped Steinmann pin may damage the posterior neurovascular structure.
Stop drilling when the far cortex is detected during the bone marrow drilling process.	

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