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ARTHROSCOPIC ASSESSMENT AND TREATMENT OF POSTERO-LATERAL CORNER (PLC) INJURIES: A COMPREHENSIVE REVIEW OF CURRENT LITERATURE

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ABSTRACT – The posterolateral corner (PLC) of the knee is a complex anatomical region, critical for maintaining joint stability, especially against varus and external rotational forces. Injuries in this region, though relatively uncommon, often occur alongside damage to other knee components, and if left untreated, may lead to persistent instability and joint degeneration. Historically, open surgical techniques have been the mainstay of PLC reconstruction. However, advancements in arthroscopic procedures have provided minimally invasive alternatives that allow precise visualization, targeted repair, and preservation of surrounding soft tissues. This paper presents a comprehensive overview of the clinical assessment and arthroscopic treatment of PLC injuries, integrating recent clinical and biomechanical evidence to guide orthopedic practice.

KEYWORDS: Posterolateral corner, Knee, Arthroscopy, Sports medicine, Anterior cruciate ligament, Posterior cruciate ligament, Multilegamentous knee injury.

INTRODUCTION

The posterolateral corner (PLC) of the knee is characterized by a complex anatomical composition. Although PLC injuries are relatively uncommon[1,2], they can significantly contribute to knee dysfunction. Such injuries frequently occur in conjunction with damage to other knee structures, underscoring the importance of their accurate identification. For high-grade lesions, timely repair or reconstruction is essential[1,3,4], as untreated cases may lead to persistent instability, characterized by a varus thrust gait and early joint degeneration[3]. Recognizing a PLC lesion is therefore crucial, especially during cruciate ligament reconstruction, as failure to diagnose it may result in premature surgical failure[5,6].

The clinical relevance of PLC injuries was first emphasized by Hughston et al[7] in 1976. At that time, the limited understanding of the anatomical structures and their biomechanics led to the PLC being referred to as the "dark side of the knee"[8]. Over the past two decades, there has been a significant enhancement in the understanding of PLC anatomy and function[9-12], which has led to the development of anatomical reconstruction techniques, resulting in marked improvements in patient outcomes[13]. While various established open-surgical techniques are available for PLC repair and reconstruction, recent advancements have introduced several arthroscopic procedures. These approaches allow for the management of different degrees of PLC injuries by repairing or reconstructing the functional structures[14].

Anatomy

The PLC consists of the popliteus complex (PTC), which includes the popliteus tendon (PLT) and the arcuate complex (AC), alongside the fibular (lateral) collateral ligament (FCL). The arcuate complex comprises the popliteofibular ligament (PFL), the fabellofibular ligament, and the popliteomeniscal fibers. The FCL serves as the primary stabilizer against varus forces[15-17], while the AC primarily provides static stability against external tibial rotation[18]. Working synergistically with the PLT, these structures collectively prevent posterior tibial translation and external rotation[19-21].

Epidemiology

The PLC is typically injured through mechanisms such as direct varus stress, hyperextension, or twisting of the knee, often in the context of multiple ligament injuries, including tibiofemoral dislocation[13]. Approximately 28% of PLC injuries occur in isolation, while up to 70% present with concomitant cruciate ligament injuries, particularly involving the posterior cruciate ligament (PCL)[19,22]. Given the high prevalence of PLC lesions in cases of multiple ligament injuries, they are also frequently associated with neurovascular damage. Vascular injury occurs in 7% to 15% of knee dislocation cases[23], while common peroneal nerve palsy is observed in around 25% of cases[24]. In particular, in the Knee Dislocation III-L type injuries, PLC lesions are significantly associated with both common peroneal nerve injury and popliteal artery injury[25].

Diagnosis

In the acute phase following a PLC injury, physical examination may be challenging due to pain and swelling, but high-grade instability is often evident. During the sub-acute phase, alongside a meticulous evaluation for cruciate and collateral ligament insufficiency, specific examination tests for the PLC should be conducted whenever feasible. Specific tests include: i) the varus stress test at 0° and 30° (if positive at 0° indicates injury to the PLC and one or more cruciate ligaments, if positive only at 30° suggests isolated LCL lesion)[7]; ii) Hughston's external rotation recurvatum test (an increase in recurvatum and external rotation compared to the contralateral side signifies a PLC lesion)[26]; iii) the dial test, performed with the patient in a prone position (an increase of 10° to 15° of external rotation at 30° of knee flexion indicates an isolated PLC injury, while at 90° it suggests a combined PCL and PLC injury)[15].

In the chronic phase, physical examination may reveal varus alignment of the weight-bearing lower limb and varus thrust gait during ambulation.

With regard to imaging, standard plain radiographs are useful for assessing joint congruence, soft tissue swelling, and fractures. Anteroposterior views may identify anteromedial tibial fractures or lateral joint line opening, while fibular head avulsion fractures (arcuate fractures) may also be visible. Varus stress radiographs at 20° can help measure lateral compartment widening, as demonstrated by LaPrade et al[27]. Magnetic resonance imaging (MRI) is indispensable in both acute and sub-acute settings, with reconstructed coronal oblique T2-weighted images proving particularly effective for evaluating PLC structures. However, in the chronic phase, more than 12 weeks post-injury, only 26% of PLC lesions can be accurately diagnosed using MRI[28]. Additionally, dynamic ultrasound stress testing has shown that a lateral joint space width of 10.5 mm or greater during varus stress achieves a sensitivity of 83% and a specificity of 100% for detecting injuries to the lateral collateral ligament and PLC structures[29].

Classification

Injuries to the PLC are commonly classified based on the structural damage to the lateral components or the extent of posterolateral rotatory instability. The two most widely adopted classification systems are the Hughston classification[30] and the Fanelli and Larson classification[31]. The Hughston classification divides PLC injuries into three grades based on clinical evaluation of varus and rotational instability with the knee in full extension. The Fanelli and Larson classification consists of three anatomical types (A-C), defined by the extent of structural damage of the PLC. A detailed overview of both systems is provided in Table 1.

Treatment

Management strategies for PLC injuries vary widely, ranging from non-operative approaches to surgical repair and reconstruction, including both anatomic and non-anatomic techniques[32-34].

Conservative treatment is generally recommended for Grade I and Grade II injuries, demonstrating favorable outcomes in restoring activity levels and showing no signs of post-traumatic osteoarthritis on radiographic follow-up[3]. For grade III injuries and grade II injuries associated with central pivot damage, surgical treatment is indicated. Direct repair of the PLC is often challenging due to extensive tissue disruption, with the focus primarily being on reattaching the FCL and other major structures to their footprints. Reconstruction typically involves using autograft or allograft tendons inserted through bone tunnels at the appropriate anatomic attachment sites[13].

In chronic Fanelli type C lesions, open anatomic reconstruction is considered the preferred treatment[35]. Such injuries often require additional refixation of the iliotibial band and/or biceps tendon, making open surgery typically essential[14]. Established procedures include Larson's[36] and Arciero's[37] fibular-based techniques, as well as LaPrade's[33] tibia and fibular-based technique.

Open surgery remains the gold standard method due to the complexity of the "dark side of the knee" and challenges associated with visualizing the anatomical relationships of the PLC during arthroscopy. Nevertheless, recent advancements in arthroscopic reconstruction techniques have shown promise, particularly for managing type 2 and type 3 injuries[14]. Arthroscopic surgery offers several advantages over open procedures, including enhanced visualization of anatomical landmarks, decreased infection risk, minimal scarring, decreased postoperative pain, faster recovery, and the avoidance of peroneal nerve preparation, thereby enhancing nerve protection[19].

ARTHROSCOPIC ANATOMY AND VISUALIZATION

Portal Creation and Approaches

The arthroscopic evaluation during PLC surgeries requires a thorough understanding of the relevant anatomical structures and poses greater challenges compared to traditional open surgery. Mastery of critical anatomical landmarks, awareness of potential at-risk structures, and proficiency in arthroscopic techniques are essential to ensure accurate and safe surgical interventions[37]. Key considerations for portal creation, including technical pearls and potential pitfalls, are summarized in Table 2.

Table 1. Posterolateral corner injury classification.

Hughston et al[30]	**Grade I**	**Grade II**	**Grade III**
	0-5 mm aperture or 0-5° rotation	5-10 mm aperture or 5-10° rotation	>10 mm aperture or >10° rotation
Fanelli and Larson[31]	**A**	**B**	**C**
	Increase in tibial external rotation	Increase in tibial external rotation plus mild-moderate instability in varus stress	Increase in tibial external rotation plus severe instability in varus stress

Table 2. Pearls and pitfalls of the arthroscopic portals for the PLC visualization.

Portal	Pearl	Pitfall
Anterolateral (AL)	Has to be enough lateral to work in the lateral gutter	If not enough lateral, the scope can impinge on the lateral condyle
Anteromedial (AM)	Has to be next to the patellar tendon	If too medial, the trans-notch view can be difficult
Posterolateral (PL)	Posterior to the LCL and anterior to the lateral gemellus at the level of the joint line	If too high or too low, debridement and visualization of key structures can be difficult. If too anterior, the LCL is at risk of damage during debridement.
Posteromedial (PM)	Find the right target with a needle probing under transcondylar notch visualization	If too posterior, instrument insertion could be difficult
Transeptal approach (TSA)	Flex the knee at 90° to keep the popliteal artery more dorsal. The shaver has to be faced toward the joint to avoid neuro-vascular damage and has to go beyond the PCL, staying very close to the bone.	Low position of the transeptal portal can damage the PCL or the popliteus muscle.

Fibular (lateral) collateral ligament (FCL); posterior cruciate ligament (PCL).

A recent cadaveric study[38] demonstrated a technique that enables complete visualization and exposure of all critical PLC structures. This approach requires four standard arthroscopic portals and an additional accessory approach: a high anterolateral (AL), anteromedial (AM), posteromedial (PM), and posterolateral (PL) portal, as well as a transseptal approach (TSA). The procedure begins with a standard diagnostic arthroscopy through the AL and AM portals. The arthroscope is then advanced through the high AL portal, passing through the intercondylar notch and beneath the posterior cruciate ligament (PCL). Under arthroscopic visualization, a needle is introduced, followed by a superficial skin incision, ensuring careful protection of the saphenous nerve[39]. Before accessing the joint capsule, needle probing is performed to assess accessibility and proper alignment, with the use of a cannula recommended in the PM portal.

The subsequent steps consist of creating the TSA. The TSA is established by positioning the arthroscope in the AM portal and advancing it under the anterior cruciate ligament (ACL) to reach the posterolateral recess. The dorsal septum is cautiously resected using a shaver through the PM portal, maintaining indirect visualization from the lateral side. Alternatively, the arthroscope can be introduced through the AL portal, passing beneath the PCL into the PM recess, allowing direct exposure of the medial aspect of the dorsal septum. Care must be taken not to extend the resection too distally in order to preserve the popliteus muscle and the PCL fibers.

Once the posterolateral joint capsule is visualized through the PM portal, a needle is inserted within the "safe triangle", bordered by the fibular FCL insertion, the lateral femoral epicondyle, and the anterior edge of the biceps femoris tendon. The PL portal is created through a blunt incision, placed anteriorly to the palpable biceps femoris tendon to mitigate the risk of peroneal nerve injury. Moreover, positioning the needle proximally and dorsally to the lateral femoral condyle and dorsal to the popliteus tendon with the knee in 90° flexion minimizes the risks of FCL injury.

PLC Structures Exposure

A radiofrequency electrode or shaver inserted through the PL portal enables precise resection of the popliteomeniscal fibers within the hiatus popliteus. This technique enhances visualization of the popliteus tendon (PLT) and the tendinous junction of the popliteus muscle from a posterior perspective. Retraction of the PLT subsequently reveals its tibial sulcus. The tibial drill tunnel exit for an arthroscopic popliteus bypass is located anterior to the popliteal muscle-tendinous junction[40]. Further preparation should focus on the dorsal aspect of the popliteus muscle.

The fibular head is palpable distal and lateral to the PLT[41]. Following intra-articular evaluation, the posterolateral joint capsule, situated directly dorsal to the PLT, is removed with a shaver. Care must be taken to avoid extending the resection beyond the posterior edge of the FH, a crucial landmark for arthroscopic PLC reconstruction.

Careful debridement of the soft tissue surrounding the PLT exposes the PFL. The PFL originates from the dorsomedial fibular styloid and inserts at the popliteal muscle-tendinous junction[9]. Arthroscopically, the PFL appears as a short, fan-shaped, reflective ligamentous structure.

The femoral attachment and the distal portion of the FCL can also be assessed arthroscopically using an additional lateral parapatellar portal. The femoral FCL and PLT attachments can be exposed through gentle soft tissue resection at the lateral femoral epicondyle[41]. The fibular attachment of FCL is located extracapsularly on the lateral side of the fibular head, distal and anterior to the styloid process and PFL attachment[9].

The femoral attachment site is covered by the tendon of the biceps femoris muscle (BT) and the most posterior fibers of the PFL[42]. These structures are exposed by resecting the most dorsal portions of the PFL and the lateral joint capsule. Visualizing the PLT's course under the FCL *via* the PM portal offers valuable guidance. The FCL is identified as a bright, cord-like ligamentous structure on the lateral aspect of the fibular head.

Neuro-Vascular Dangers

Arthroscopic procedures in the posterior compartment of the knee present significant challenges due to the anatomical proximity of critical neurovascular structures, particularly the popliteal artery (PA) and the peroneal nerve[43]. Despite the associated risks, numerous studies[19,41,44-46] have demonstrated the safety of the transseptal approach (TSA) when performed with proper technique.

The PA is located anteriorly within the popliteal neurovascular bundle[47]. At the level of the joint line, it lies close to the dorsal septum, posterior and slightly lateral (2-3 mm) to the PCL[47-49]. As the PA extends distally, its distance from the posterior capsule decreases, reaching its minimal separation approximately 1 cm below the joint line, where it is shielded by the fibrous portion of the soleus muscle[49,50]. This anatomical relationship increases the risk of PA injury during posterior knee arthroscopy, particularly when preparing the TSA or drilling the tibial tunnel[50,51].

The safety margin in the posteromedial compartment is greater than that of the posterolateral compartment. Removing the septum from medial to lateral facilitates precise postero-lateral portal placement, using the popliteus tendon as the key anatomical landmark[52].

Modifying the knee's position can significantly reduce the risk of vascular injury. Increasing knee flexion widens the posterior clear space by shifting the PA posteriorly[53]. During full extension, the PA is situated 5.4 mm from the tibial PLC attachment, with this distance nearly doubling to 9.7-9.9 mm at 90-100° of flexion[53,54]. At 90° of knee flexion, the distance from the PA to the PCL center is approximately 29 mm[54]. Therefore, maintaining the knee in 90° flexion is highly advisable to conduct arthroscopy involving the posterior recess.

The lateral inferior genicular artery, which is located dorsal to the popliteus tendon and lateral to the soleus muscle, is also at risk for iatrogenic injury. Utilizing a radiofrequency electrode for cauterization minimizes the likelihood of significant bleeding and an arthroscopic "red out," reducing the risk of complications[55].

Arthroscopic neurolysis carries a risk of peroneal nerve injury. While neurolysis is obligatory in open-surgery reconstruction of PLC, it is not indicated for arthroscopic techniques[56]. Nonetheless, an in-depth understanding of anatomical relationships is crucial, especially during arthroscopic PLC reconstruction surgery. Since the peroneal nerve is typically not visible during these procedures, maintaining awareness of anatomical landmarks and carefully managing the angle and height of the fibular drill channel can mitigate the risk of nerve injury[41,56]. To further minimize the risk of iatrogenic peroneal nerve damage, blunt instruments are preferred over shavers and RF devices when approaching the inferior border of the biceps femoris[44]. This approach enhances safety by reducing the potential for unintended nerve injury.

ARTHROSCOPIC PLC RECONSTRUCTION

Several arthroscopic techniques have been developed to address the distinct biomechanical components of PLC instability, each targeting specific deficits such as external rotational laxity, varus instability, or both.

Addressing Isolated Rotational Instability

Several fully arthroscopic methods focus on restoring the popliteus complex's restraint against external tibial rotation:

Sling reconstruction of the popliteus tendon (Feng et al[57]): a non-anatomical approach that uses a semitendinosus autograft routed through a femoral PLT tunnel and an ACL-style tibial tunnel to re-tension the popliteus musculotendinous junction. It alters the native course of the tendon but provides sufficient resistance against external rotation. Early outcomes are encouraging, though long-term data are limited.

Popliteus bypass graft (Frosch et al[19]): anatomically restores the static function of the popliteus by placing a semitendinosus graft from a tibial drill tunnel (*via* a transseptal approach) to a precisely located femoral PLT footprint. Its design aims to closely mimic the native fiber orientation and tension (tunnel placement shows <3 mm deviation from anatomic landmarks[58]), with one-year follow-up demonstrating normalization of dial-test findings.

Fibula-based PFL reconstruction (Song et al[46]): considered anatomical, this technique targets pure rotational laxity by drilling a fibular tunnel at the PFL insertion and a femoral socket *via* an accessory lateral gutter portal. A semitendinosus (or tibialis anterior allograft) is passed from the fibula to the femur and fixed with interference screws. A single-case follow-up at two years demonstrated restored external rotation stability.

Arthroscopic Popliteus Tenodesis (Hermanowicz et al[59]): a non-anatomical stabilization with midlateral-portal technique that attaches the native popliteus tendon to a tibial button, effectively converting it into a static check against external rotation. While biomechanically effective in selected cases, this does not restore the original tendon path or role in joint motion, and it carries a risk of iatrogenic meniscal injury.

Reinforcing Capsular Laxity

In cases where excessive posterolateral joint opening is due to capsular laxity rather than ligamentous disruption, focused repairs may suffice with a posterolateral capsule stabilization[60]. It is a non-anatomical technique that reinforces the PLC by suturing the lateral meniscus, popliteomeniscal fibers, and posterolateral capsule to the lateral tibial rim *via* two midlateral-portal anchors. It limits lateral meniscal motion but offers a minimally invasive solution for isolated rotational laxity.

Restoring Combined Rotational and Varus Stability

For higher-grade PLC injuries involving both varus and rotatory instability (Fanelli type B/C or type 3 combined), multibundle or multitunnel reconstructions are required:

Fibula-based anatomic PLC reconstruction (Arciero-Derived, Frings et al[61]): an anatomical approach that arthroscopically replicates Arciero's dual-bundle open reconstruction with two independent femoral tunnels at the native PLT and FCL footprints plus a fibular tunnel for gracilis graft passage and fixation. This method aims to restore both directional stability and ligament kinematics using a gracilis graft and demonstrates biomechanical fidelity to native PLC architecture.

Arthroscopic-assisted PLC + FCL reconstruction (Hermanowicz et al[62]): combines semitendinosus for the PLT graft and gracilis for the FCL through high midlateral portals and separate open incisions for fibular/femoral FCL tunnels. It is designed for the highest-grade (type 3) instabilities to stabilize both tibiofemoral and proximal tibiofibular joints.

Tibia + fibula-based anatomic reconstruction (LaPrade[33]-Inspired, Kolb et al[63]): a thoroughly anatomical technique built on high-fidelity anatomical and biomechanical principles. It employs four tunnels [TSA, a fibular tunnel from the FCL attachment to the PFL footprint, a tibial popliteal sulcus tunnel, and dual femoral tunnels (FCL and PLT) under lateral parapatellar view] and two grafts to simultaneously address rotational and varus laxity while preserving tibiofibular articulation. Although experimental in nature, it represents one of the most anatomically comprehensive reconstructions available.

A concise comparison of the main arthroscopic PLC reconstruction techniques is presented in Table 3, highlighting their clinical indications, levels of evidence, graft choices, follow-up duration, and unique technical or rehabilitative advantages.

Table 3. Overview of arthroscopic techniques for posterolateral corner reconstruction based on indications, evidence level, graft selection, and clinical benefits.

Technique	Indication	Level of evidence	Graft source	Follow-up duration	Key advantage
Sling reconstruction (Feng et al[57])	Fanelli Type A	IV (case series)	Semitendinosus autograft	<6 months	Minimally invasive; simple tunnel work
Popliteus bypass graft (Frosch et al[19])	Fanelli Type A	II (prospective cohort)	Semitendinosus autograft	12 months	Anatomic footprint accuracy (<3 mm)
Fibula-based PFL reconstruction (Song et al[46])	Fanelli Type A	IV (single case)	Semitendinosus or tibialis anterior allograft	24 months	Direct PFL restoration
Capsule stabilization (Ohnishi et al[60])	Fanelli Type A	IV (short-term series	Native capsule and meniscal tissues	<6 months	No graft harvest; fastest recovery
Arciero-derived PLC reconstruction (Frings et al[61])	Type 3 (combined)	II (prospective 66)	Gracilis autograft	6-12 months	Restores both rotatory and varus laxity
Arthroscopic-assisted PLC + FCL (Hermanowicz et al[62])	Type 3	IV (case series)	Semitendinosus (PLT) + Gracilis (FCL)	6-12 months	Addresses tibiofibular instability
LaPrade-Inspired fibula/tibia PLC (Kolb et al[63])	Fanelli Type B/C (severe combined)	IV (biomechanical only)	Two autografts	N/A	Most anatomic dual-bundle construct

"N/A" indicates data not specified in the cited technique description. Fibular (lateral) collateral ligament (FCL); posterior cruciate ligament (PCL); popliteofibular ligament (PFL); popliteus tendon (PLT).

ARTHROSCOPIC TREATMENT'S EFFECTIVENESS IN CHRONIC PLC INJURIES

Acute treatment (within 3 weeks) is reported to have improved outcomes, while treatment after 3 weeks has been reported to have similar outcomes to chronic injuries[64]. Chronic PLC injuries (greater than 6 weeks from injury) may determine a varus thrust gait. Therefore, lower extremity alignment should be evaluated and corrected prior to ligament reconstruction, as failure to address malalignment can lead to increased stress and stretching of the reconstruction grafts, ultimately resulting in failure. Despite these challenges, arthroscopic reconstruction has proven feasible and effective in chronic cases, offering lower morbidity compared to traditional open techniques and allowing refined anatomical restoration when performed with expertise[65,66]. Studies[65] have demonstrated that anatomical reconstruction techniques, such as fibula- and tibia-based methods inspired by LaPrade, yield favorable outcomes in chronic settings, restoring rotational and varus stability with high accuracy. Ultimately, it is the patient selection, the surgical planning, and, mostly, the surgeon's experience that leads to successful outcomes in arthroscopic reconstructions[67].

DISCUSSION

The arthroscopic techniques outlined above differ in several key aspects. However, limited clinical data are available regarding the outcomes. Although numerous studies in the literature have reported promising biomechanical and clinical outcomes for arthroscopic PLC reconstructions, open-surgical procedures continue to be the preferred choice for treating PLC instabilities. These techniques offer reliable access to key anatomical landmarks and allow for precise graft placement, especially in high-grade or combined injuries involving varus and rotational instability. Numerous studies[33,36,37] have demonstrated favorable outcomes following open PLC reconstructions, particularly with techniques such as fibular-based or tibiofibular-based reconstructions, which restore key static stabilizers, including the FCL, PLT, and PFL.

In contrast, arthroscopic PLC reconstruction is an emerging field, offering the potential advantages of reduced soft tissue disruption, enhanced visualization of intra-articular and periarticular structures, and potentially faster recovery times. Early clinical outcomes from these techniques are promising, with reports indicating restoration of external rotation stability and normalization of clinical laxity tests, particularly in isolated rotational injuries[57,60-63]. Despite these advantages, the current evidence base supporting arthroscopic PLC reconstruction remains limited. Most studies are retrospective in nature, involve small patient cohorts, and are primarily case series or technical notes. As highlighted in a recent systematic review[68], the overall level of evidence remains low, with only a minority of studies reaching Level III. Furthermore, heterogeneity in technique, graft choice, and target structures makes direct comparison across studies difficult. Biomechanical data are also inconsistent, with a wide range of testing protocols and outcome measures used, further complicating efforts to draw definitive conclusions.

Concerns about the technical complexity of arthroscopic procedures persist, particularly regarding tunnel placement and proximity to neurovascular structures. While no neurovascular injuries have been reported in the current literature, expert commentary has repeatedly emphasized the steep learning curve and potential risks associated with arthroscopic approaches[57,69]. Nonetheless, arthroscopic techniques offer a targeted, tissue-sparing alternative that may prove especially beneficial in acute, isolated injuries or in patients with specific anatomical considerations.

CONCLUSIONS

Given these factors, there remains an urgent need for high-quality comparative studies to better define the indications, efficacy, and safety of arthroscopic PLC reconstruction relative to open procedures. Prospective randomized trials, larger multicenter cohorts, and standardized biomechanical testing protocols will be essential to determine whether the theoretical advantages of arthroscopy translate into superior clinical outcomes. Until such data are available, the use of arthroscopic techniques should be approached with caution, particularly by less-experienced surgeons, and ideally reserved for centers with appropriate expertise.

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Conceptualization, L.I.; methodology, L.I.; validation, G.M.P. and C.S.; formal analysis, A.P.; investigation, L.I. and A.P.; resources, L.I. and A.P.; data curation, C.S.; writing-original draft preparation, L.I.; writing-review and editing, F.S; reviewing and editing, N.R.; visualization, A.P.; supervision, C.S.; project administration, N.R.; All authors have read and agreed to the published version of the manuscript.

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