The Popliteus Tendon Provides a Safe and Reliable Location for Anchor Placement: Outcome of 200 Posterior Horn Lateral Meniscal Repairs Performed at the Time of ACL Reconstruction

ABSTRACT

Background: Tears of the posterior horn of the lateral meniscus are challenging to repair because, in contrast to medial meniscal repairs, the capsule and its attachment are thin.

Purpose: To evaluate the clinical results of an arthroscopic all-inside repair technique for unstable, vertical, lateral meniscus tears, using a suture anchor device placed directly into the popliteus tendon.

Study Design: Case Series; Level of evidence, 4.

Methods: A retrospective analysis of prospectively collected data from the ***** database was performed. All patients who had undergone combined ACL reconstruction with lateral meniscus all-inside repair, using sutures placed in the popliteus tendon, between January 2011 and February 2015, were included. At final follow-up, all patients were contacted by telephone to identify if they underwent further surgery or had pain, locking or effusion. Symptomatic patients were recalled for clinical/imaging evaluation. Operative notes for those undergoing further surgery were reviewed and rates and type of re-operation, including for failed lateral meniscal repair were recorded.

Results: Two hundred patients (mean age, 28.6 ± 10.2 years) with a mean follow-up of 45.5 ± 12.8 months (range, 24.7-75.2) were included. The mean Subjective International Knee Documentation Committee (IKDC) at final follow-up was 85.0 ± 11.3. The post-operative mean side-to-side laxity measured at one year was 0.6 ± 1.0 mm. Twenty-six patients underwent re-operation (13%) at a mean follow-up of 14.8 ± 7.8 months. The ACL graft rupture rate was 5.0%. Other causes for re-operation included medial meniscus tear (2.5%), cyclops lesion (1.5%) and septic arthritis

(0.5%). The lateral meniscus repair failure rate was 3.5%. No specific complications relating to placement of suture anchors in the popliteus tendon were identified.

Conclusion: Arthroscopic all-inside repair of unstable, vertical, lateral meniscal tears using a suture anchor placed in the popliteus tendon is a safe, efficient and reproducible technique. It is associated with a very low failure rate without specific complications.

Key-Words: ACL rupture, lateral meniscus tears, all-inside repair, meniscal repair, popliteus tendon

What is known about the subject: Tears of the posterior horn of the lateral meniscus can be challenging to repair. In contrast to medial meniscal repairs, the capsule and its attachment are thin. Using popliteus as a location for anchor placement is an option for improving the biomechanics of the repair but there is concern that anchor placement in popliteus may cause iatrogenic injury or irritation to this structure or result in premature suture failure. However, to the authors knowledge, there is no clinical data to support this. In contrast, there is laboratory evidence to demonstrate that loosening does not occur in sutures placed in popliteus after 1000 loading cycles and there are some small case series reporting that the technique is safe

What this study adds to existing knowledge: This study is the first large series to comprehensively report outcomes in a large series of patients undergoing repair of unstable, vertical, lateral meniscal tears with a suture placed in popliteus at the time of

ACL reconstruction. The excellent clinical results and lack of complications serves to dispel the myth that popliteus should not be used as a location for anchor placement and gives surgeons the confidence to add this useful, safe and reliable technique to their armamentarium for dealing with these repairs.

Introduction

The association of concurrent meniscal tears with anterior cruciate ligament (ACL) rupture represents a common and severe injury pattern that typically occurs in young, active individuals.[6,9,22,23,35] Approximately 65% of ACL injured knees are reported to occur in combination with a meniscal injury but not all of these require treatment.[40] In particular, stable posterior horn tears of the lateral meniscus left in-situ at the time of ACL reconstruction are reported to demonstrate satisfactory healing with functional restoration.[16] In contrast, unstable tears have important biomechanical consequences and warrant treatment.[1,25,33] This can include repair or meniscectomy, but it is clear that the latter should be avoided when possible. This is because meniscectomy is associated with abnormal joint kinematics, significant increases in articular cartilage peak contact pressures, elevated shear stresses, a predisposition to early degenerative change and even rapid chondrolysis.[5,12,20,26,29] Consequently, meniscal repair is widely considered to be the treatment of choice for these lesions.[40] When a repair is performed at the same time as ACL reconstruction, good long-term repair survivorship is reported with only a 14% failure rate for both medial and lateral repairs at 6-years follow-up.[40]

The all-inside repair technique is the most frequently used in current clinical practice.[40] Uchida, *et al.* demonstrated that good fixation can be reliably achieved with an all-inside technique in medial meniscal repair because most anchors placed were found to be located securely on the capsule.[38] In contrast, on the lateral side, only anchors fixed in the area posterior to the popliteus tendon, in the posterior part of the popliteal hiatus, reliably provided secure fixation on the capsule. More posteriorly, all anchors were located intra-capsularly. This was attributed to the fact that the capsule is not as tightly opposed to the lateral meniscal body as it is to the medial meniscus.[38] Furthermore, the capsule around the posterior root attachment of the lateral meniscus is quite thin.[38] Although the authors also secured anchors within the popliteus tendon, they advised against this because of theoretical concerns regarding iatrogenic injury or irritation to this structure and suture loosening during knee movement.

The purpose of this study was to evaluate the clinical results of arthroscopic all-inside repair of unstable vertical lateral meniscus tears, using a suture anchor device placed in the popliteus tendon. It was hypothesized that this technique would be reproducible, safe and associated with a low re-operation rate for failure of repair.

Methods

This study received institutional review board approval and was performed in accordance with the Declaration of Helsinki ethical standards.

Between January 2011 and February 2015, the senior surgeon (***) performed 1835 anterior cruciate ligament reconstruction (ACLR) procedures. All patients had sustained a knee injury with a diagnosis of ACL rupture based on clinical examination and magnetic resonance imaging (MRI). A retrospective analysis of prospectively collected data from the ***** database was performed. All patients who had undergone combined ACLR and all-inside repair of the lateral meniscus using sutures placed in the popliteus tendon were identified. Failure was defined as the need for revision repair or meniscectomy for the lateral meniscus. The following groups of patients were excluded from the study: multi-ligament injuries, revision ACLR, other major concomitant procedures (e.g. high tibial osteotomy), discoid lateral meniscus, complex lesions of the lateral meniscus (posterior root avulsion, radial tear or bucket handle) and paediatric cases.

The indication for all-inside repair of the lateral meniscus using sutures placed in the popliteus tendon was anterior displacement of the posterior meniscal segment under the central part of the femoral condyle on probing. This is indicative of an unstable tear, and synonymous with pathological hypermobility that could result in pain and locking.

Surgical technique:

Patients were positioned supine in the standard arthroscopy position. A lateral post was placed just proximal to the knee, at the level of the padded tourniquet, and a foot roll was used to prevent the hip from externally rotating and to maintain 90° of knee flexion. In this way, the knee could be moved freely through the full range of motion.

The anterolateral portal was created adjacent to the lateral edge of the patellar tendon and the inferior border of the patella. The anteromedial portal was positioned just below the inferior border of the patella and approximately 4 mm medial to the medial border of the patellar tendon. A full diagnostic arthroscopy was performed and meniscal and cartilage procedures were undertaken prior to ACL reconstruction.

For assessment of the lateral compartment, the knee was placed in the "figure of four" position and the lateral meniscus was probed. When an unstable tear of the posterior horn of the lateral meniscus was identified, a simple all-inside meniscal repair device (Ultra Fast-Fix®, Smith & Nephew, Andover, USA) was introduced through the anteromedial portal, and a suture was placed in the popliteus tendon after debridement of the tear (Figure 1).

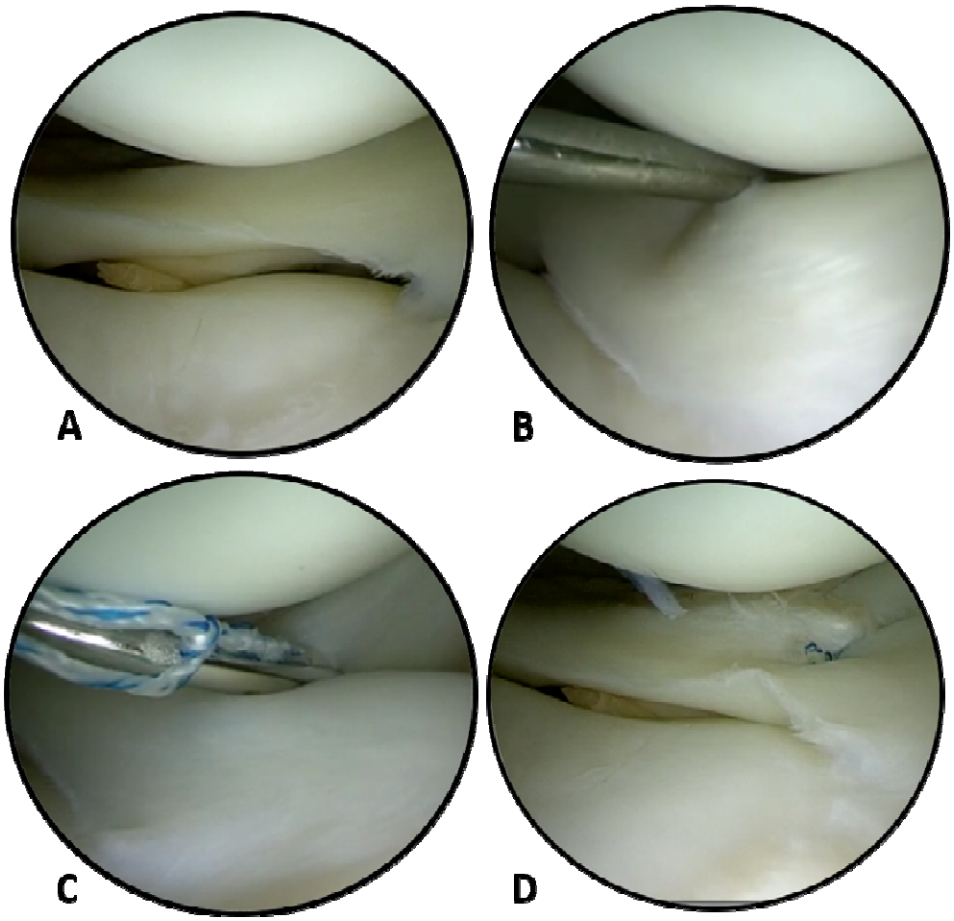


FIGURE 1: Arthroscopic view of lateral compartment of a left knee via anterolateral portal.
A: Posterior horn, vertical, lateral meniscal tear. B: Probing reveals tear is unstable.
C: Placement of meniscal suture device into popliteus tendon. D: Final appearance of repair

For medial meniscus tears, an all-inside or outside-in technique was used for ruptures in the body and posterior horn of the meniscus. A systematic arthroscopic exploration of the posteromedial portion of the meniscus was performed to identify any additional lesions. These were treated using an all-inside technique through a posteromedial portal, as previously described.[2,21] Finally, ACLR was performed using either bone-patella tendon-bone or hamstring tendon autograft. Some patients also underwent a lateral extra-articular tenodesis. [30,31]

Rehabilitation

Postoperatively, the active and passive range of motion was limited from 0º to 90º in the first 4 weeks, with immediate full weight-bearing. Jogging was permitted after 3

months, pivoting activities at 6 months, and full activity at 9 months.

Outcomes

Examinations were conducted pre-operatively and at the following post-operative intervals: 3 and 6 weeks and at 3, 6, and 12 months. Patient demographics such as gender, age and BMI were recorded as well as Lachman's test. At 6 months post-operatively, all patients underwent isokinetic testing prior to returning to sport. When the isokinetic test showed a deficit greater than 20% in the eccentric or concentric hamstring strength or any quadriceps deficit, return to sport was deferred and repeat testing was performed 2 months later. Side-to-side laxity was evaluated at 12 months follow-up for all patients using the Rolimeter Arthrometer® (Aircast, Europe).

At the end of the study period all patients underwent a telephone interview, performed by a physician who was not the primary surgeon (XX). This comprised the following standardized questions:

- Subjective IKDC questionnaire.
- Did you return to sport? If yes, which sport and at what level?
- Did you have a second operation / revision after your ACLR?
- Did you have a contralateral ACL rupture or contralateral ACLR after the index procedure?
- Do you have any swelling? Do you have any locking sensation? Do you have any pain?

Operative records were reviewed for all patients who underwent further surgery. If patients reported knee pain, effusion, or symptoms of locking they were recalled for clinical review and imaging if indicated.

Statistical Analysis

Therapeutic variables (surgery, adjuvant therapy, and function) and demographic variables (sex, age, and follow-up) were examined. Descriptive data (mean, median, range, proportions) are reported for the entire patient cohort. Differences between means were tested with the t-test for continuous variables; or with the Mann-Whitney test when data were not normally distributed. Categorical variables were tested with the Chi^2 test or the Fischer exact test. A probability value of $p \leq 05$ was considered

statistically significant. A Kaplan-Meier survivorship analysis of LM repair using re-operation as an endpoint was performed using GraphPad software (Version Prism 7, GraphPad Software Inc., California, USA). All other calculations were made using SPSS software (Version 20.0, SPSS Inc., Chicago, IL).

Results

The overall study population comprised 1835 primary ACLRs. Figure 2 illustrates the flow of patients. Lateral meniscal tears were identified in 450 patients, of which 380 (84.4%) underwent repair. Of the lateral meniscal repairs, 251 had all-inside repairs using sutures placed in the popliteus tendon. After application of the exclusion criteria, 213 repairs were included in the study. Thirteen patients (6.1%) were lost to follow up despite attempts to contact them by telephone, mail and via their general practitioner. The final study population therefore comprised 200 patients who had undergone primary ACLR and a lateral meniscus repair using a suture anchor in the popliteus tendon.

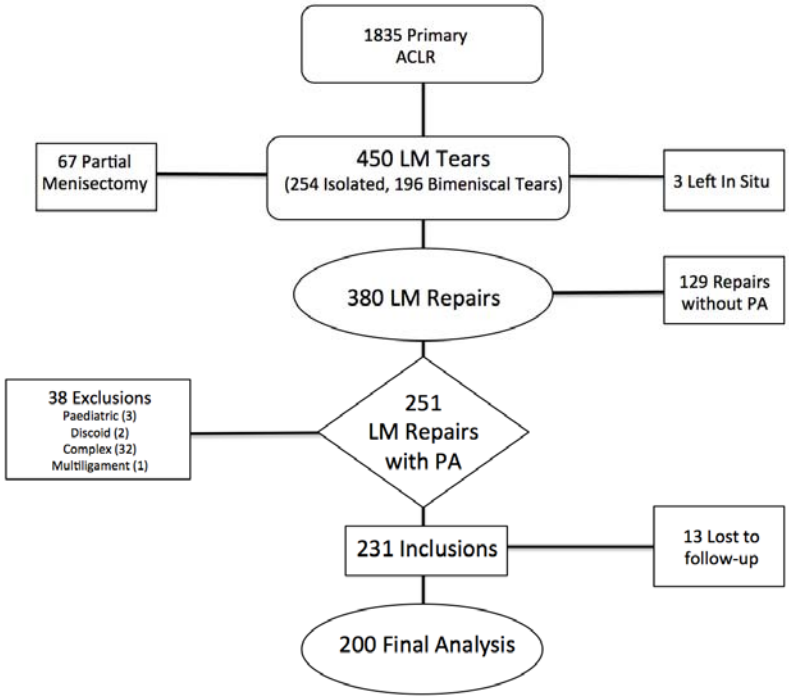


FIGURE 2. Flowchart illustrating the flow of patients through the study; ACLR (Anterior Cruciate Ligament Reconstruction), LM (Lateral Meniscus), PA (anchor placed in popliteus tendon).

Demographic data

Demographic data including age, gender distribution, BMI, time between injury and surgery and duration of follow up are reported in Table 1. Details of the surgical procedures including ACL graft type, and the management/type of meniscal pathology is reported in Table 2.

TABLE 1: Patient Demographics

	All Patients (N=200)
Follow-up, mean ± SD (range), months	45.5 ± 12.8 (24.7-75.3)
Male sex, n (%)	139 (69.5)
Age, mean ± SD (Range), years	28.6 ± 10.2 (14-60)
Time from injury to surgery, mean ± SD (Range), months	16.8 ± 50.4 (0.1-364.1)
Weight (kg)	75 ± 14.6 (47-125)
Height (cm)	175.3 ± 9 (150-200)
BMI (kg/m^2)	24.3 ± 3.6 (15.3-36)

Clinical results

The pre operative antero posterior side to side laxity was 7.4 mm ± 1.5 (4-12). At 12 months follow-up, the mean residual side to side laxity was 0.6 mm ± 1 (-3 to 3). At a mean final follow-up of 45.5 ± 12.8 months (range, 24.7-75.2), the mean subjective IKDC score was 85.0 ± 11.3 (37.9 to 100). 180 patients returned to sports activity with 97 returning to competition.

TABLE 2: Summary of surgical procedures performed

BPTB: Bone-Patellar Tendon-Bone
4HT: Hamstring Tendon (Semitendinosus + gracilis)
ST: Semitendinosus
EAT: Extra Articular Tenodesis
LM (Lateral Meniscus), MM (Medial Meniscus)

ACL		
Graft Type	N	Lateral Tenodesis N
BPTB	21	3
Classic 4HT	72	6
Single ST	27	2
HT + EAT	80	80
TOTAL	200	91
MENISCAL TEARS		
Type	N	%
Isolated Vertical Unstable LM Tear	116	58
Vertical Unstable LM Tear + MM Tear (67 MM Repairs + 17 Medial Meniscectomies)	84	42
LM Tear sutured with 1 Fast fix	111	55
LM tear sutured with more than 1 fast fix	89	45

Re-operation

Twenty-six patients (13%) underwent ipsilateral re-operation at a mean follow up of 14.8 ± 7.8 (5.9-43.5) months. Failure of lateral meniscal repair occurred in 7 knees (3.5%) at a median follow-up of 24.2 ± 15.3 (8.7-43.5) months. ACL graft failure leading to revision surgery occurred in 10 knees at a median of 16.7 ± 7.1 (8.4-26) months after the index procedure. There were 9 ipsilateral re-operations for indications other than graft rupture and lateral meniscal repair failure (medial meniscus n=5, cyclops syndrome n=3, arthroscopic lavage with infection n=1). With respect to the contralateral knee, 14 patients (7%) had a contralateral ACL rupture after the index procedure (Table 3).

TABLE 3: Complications

	N (%)	Time to Revision (Months)	Procedure
LM Suture Failure	7 (3.5%)	24.2 ± 15.3 (8.7-43.5)	LM Re-suture (N=4) or LM Meniscectomy (N=3)
MM tear	5 (2.5%)	9.8 ± 3.9 (6.3-16)	MM Meniscectomy
ACL Re-rupture	10 (5%)	16.7 ± 7.1 (8.4-26)	ACL Revision
Cyclops	3 (1.5%)	6.1 ± 0.3 (5.9-6.5)	Arthroscopic Arthrolysis
Septic Arthritis	1 (0.5%)	11.74	Lavage + ATB
Complex Regional Pain Syndrome	1 (0.5%)	No Revision	Medical Treatment
Contralateral ACLR	14 (7%)	No Revision	ACL Reconstruction
Total Number of Re-operations	26 (13%)	14.8 ± 7.8 (5.9-43.5)	

LM (lateral meniscus), MM (medial meniscus), ACL (anterior cruciate ligament reconstruction)

The re-operation rate for failure of LM repair (3.5%) was lower than the failure rate of MM repair (7.5%), but this difference was not significant ($p = 0.18$, Fischer exact test). Patients who underwent both medial and lateral meniscal repairs at the index procedure were significantly more likely to undergo re-operation for failure of LM repair ($p= 0.0021$, Fischer exact test). Furthermore, the overall reoperation rate (for any indication) in patients who underwent both medial and lateral repairs (22.4%) was greater than in patients who underwent isolated LM repair (9%) and this difference was significant ($p= 0.005$ Chi^2).

The re-operation rate for failure of LM repair in patients who underwent lateral tenodesis (2.2%) was lower than in patients without lateral tenodesis (4.6%) but this was not significant (p= 0.5, Fischer exact test). Patients whose LM tear was repaired with more than one Fast-Fix placed in popliteus had a failure rate of 5.6% versus 1.8% in patients whose repair was performed with only one Fast-Fix device. This difference was not significant (p=0.1 Fischer exact test).

Knee pain at final follow-up

This criterion was evaluated after excluding the patients who underwent re-operation. Of 174 patients, twenty-nine reported discomfort, or some pain in the knee, with a mean visual analogue scale of 3.6 out of 10. Only, 3 patients reported pain on the lateral side of the knee. In those 3 patients, the clinical assessment revealed specific pain localised proximal to the femoral lateral epicondyle. There was no tenderness on joint line palpation and no indication for further imaging. All 3 patients received an extra-articular corticosteroid injection and remain pain free at final follow-up. No patients reported posterior pain in the region of the popliteus anchors.

Specific complications of sutures placed in the popliteus tendon

No complications were directly related to anchors placed in the popliteus tendon. Specifically, no patients had surgery to remove a symptomatic device placed within the popliteus tendon. 7 patients (3.5%) required re-operation for failed lateral meniscus repair. Intra-operative findings comprised horizontal tears of the posterior horn (n=3) or the body (n=2), flap tear of the posterior horn (n=1) and recurrent vertical unstable lesion (n=1). At surgery, a revision repair was performed in 3 patients and a partial meniscectomy was performed in the remaining 4 patients. Among the other 19 re-operations, 10 patients sustained a new knee injury that resulted in graft failure and revision ACLR. A recurrent traumatic lesion of the lateral meniscus was found in 8 patients leading to either repair (n=6) or meniscectomy (n=2). In other re-operations, the lateral meniscus repair was found to be completely healed with the hiatus recreated, as previously reported by other authors.[39] There were no cases of popliteus tendon tear, or neurological injury.

Figure 3 shows the cumulative survivorship of lateral meniscal repairs derived from Kaplan-Meier analysis when using re-operation for lateral meniscal pathology as an endpoint.

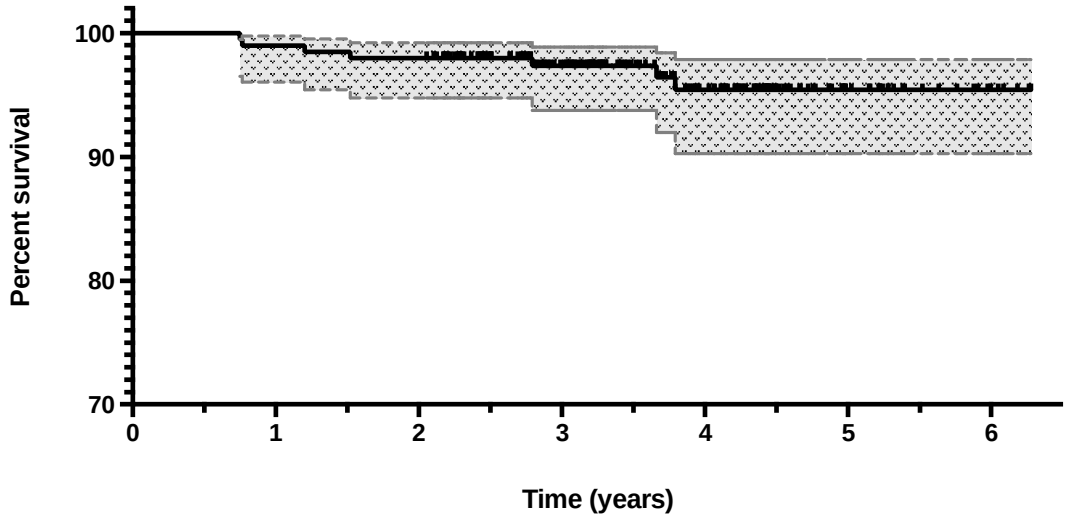


FIGURE 3: Kaplan-Meier plot showing survivorship of lateral meniscal repairs (performed with a suture placed into the popliteus tendon) when using re-operation for lateral meniscal pathology as an endpoint.

Discussion

The most important finding of this study is that all-inside repair of peripheral, vertically unstable, lateral meniscal tears using suture anchors placed in the popliteus tendon is safe, reproducible and associated with excellent clinical outcomes. A low failure rate of meniscal repair (3.5%) at a mean follow up of 45 months (range 24.7-75.3), without any specific complications was observed. To the author's knowledge, this is the first clinical study of a large series of lateral meniscal repairs performed with suture anchors placed in the popliteus tendon.

Previous authors have drawn attention to the concern that anchors placed in popliteus may become loose or cause pain and irritation with knee motion.[17,38,42] However, a literature search performed for the current study did not reveal any clinical studies to support this concept. These results are consistent with the outcomes of the current study in which no cases of pain or irritation due to implant breakage, articular migration, foreign-body reaction, cyst formation or popliteus irritation were encountered.

The dynamic and static roles of the intra-articular portion of the popliteus tendon are still debated. LaPrade *et al.* demonstrated that the popliteus tendon has important dynamic and static stabilizing functions and named it "the fifth ligament of the knee".[15] In contrast, other authors have reported that the popliteus muscle–tendon unit has extensive fibular, capsular-meniscal and tibial attachments.[24,36,37] As such it is considered that the intra-articular portion of the popliteus tendon is very stable and relatively immobile in the segment from the popliteus fossa to the arcuate ligament. This is supported by additional studies which demonstrate minimal motion of the intra-articular portion of popliteus during knee motion.[13,32] Furthermore, Lopez *et al.* demonstrated in a cadaveric, biomechanical study that sutures placed in the popliteus tendon did not show any macroscopic sign of failure or gapping of the repair after 1000 gait cycles. It was concluded that closure of the popliteal gap during a lateral meniscus repair probably has minimal repercussions on the kinematics of the posterolateral knee angle and in some cases, may imply a greater repair strength.[19]

The role of the popliteus tendon may be further delineated if we look closely at its phylogeny. Interestingly, the fibula in protomammals receded distally from its

position at the femorotibial joint line, to the position where it currently exists in modern mammals. With fibular recession, the popliteus muscle attachment that previously was connected directly to the proximal fibula, became attached to the lateral femoral condyle through a tendinous transformation of the primitive femorofibular meniscus that was present in earlier tetrapod species.[8] This concept was previously described by Kaplan.[13] Given that the popliteus tendon is derived from a relatively static primitive meniscus structure may explain why it is a suitable anchoring point for an unstable lateral meniscus. The authors believe that the popliteus tendon used in this way acts as a temporary brace for the lateral meniscus during healing.[4]

The concept of using the popliteus tendon for anchor fixation has previously been described in the literature.[4,19,28,39] Verdonk *et al.* reported using this strategy when performing lateral meniscus allograft transplantation. They described that in second-look arthroscopies, the popliteal hiatus had recreated itself naturally.[39] Shelbourne *et al.* reported a low failure rate using the popliteus tendon as a location for anchor placement when repairing unstable lateral meniscal tears combined with ACL reconstruction (2% failure rate on unpublished data from 2011).[28] Similarly, Ahn *et al.* reported satisfactory clinical results in a series of 24 arthroscopic lateral meniscal repairs at 41 months follow-up.[3] In their technique, they describe an all-inside repair for posterior horn lesions and note that "when the posterolateral capsule was weak, the suture was applied between the meniscus of the posterior horn and capsule, including the popliteus tendon." They had no re-operations and concluded that their technique was safe.

Lateral meniscal tears in the region of the popliteus tendon have been regarded as a difficult area to repair.[34] Horibe *et al.* noted low healing rates (19 of 30, 63%) on second look arthroscopy with meniscal tears in the region of the popliteus tendon, in a series of 278 meniscal repairs using an inside-out technique.[11] They suggested it may be due to the absence of a synovial fringe seen on microangiographic studies of this region.[11] However, it is also recognised that tears near the popliteal hiatus are challenging because the lateral meniscus has a weak attachment posteriorly. This is not ideal for secure anchor fixation. Uchida *et al.* demonstrated that in this region there is a high rate of failure to capture the capsule with an all-inside device.[87] This

appears consistent with the study of Kashihara *et al.* who reported that all-inside lateral meniscal repairs are associated with significant increases in post-operative radial meniscal extrusion.[14] They suggested that the reasons for this are multifactorial, but included that it was because the suture device moves the meniscus to where it is captured on the peripheral joint capsule.[14] This is an important consideration because meniscal extrusion increases joint contact pressures and predisposes to early degenerative change.[7] It therefore seems logical to try and improve the stiffness of meniscal repair in tears around the popliteal hiatus.

The current study demonstrates that placing sutures in the popliteus tendon is safe and associated with good results. Further study is required to determine whether it has any influence on meniscal extrusion or joint contact pressures when compared to other techniques. The main finding from this study is that the previously widespread belief that suture placement in the popliteal tendon should be avoided is not supported by clinical results from a large series. However, there was a non-significant trend towards an increased failure rate of LM repair when two anchors were placed in popliteus rather than one. The indication for the placement of two anchors was not precisely defined and was based on surgeon preference. Interpretation of this finding is therefore somewhat limited. It is postulated that placement of two anchors may overconstrain the meniscus thus predisposing to failure of the repair. However, this requires further study. Despite this trend towards increased failure, even in the two anchor group, the re-operation rate for LM repair failure was low at 5.6%, at a mean follow up of over 45 months.

This study has some limitations. Firstly, it involved a retrospective review of prospectively collected information, without a control group, and relied on a telephone-based questionnaire for initial assessment of patients, rather than clinical examination. However, recalling young geographically mobile, asymptomatic patients is difficult and previous authors have used telephone questionnaires in similar populations.[10] We did not perform routine second-look arthroscopy or MRI imaging in asymptomatic patients and so the true failure rate is likely to have been higher than the rate that was clinically apparent. Furthermore, the minimum length of follow-up was relatively short (24.7 months) particularly as it is recognized that the risk of symptomatic meniscal lesions developing after ligament reconstruction is highest

within the first 4 years after the index procedure.[18,27] Despite these limitations, the strength of this study is the large number of consecutive patients that underwent repair of vertical, unstable, posterior horn lateral meniscus tears using the same technique.

Conclusion:

Arthroscopic all-inside repair of unstable, vertical lateral meniscus tears using a suture anchor device placed in the popliteus tendon is a safe technique. It is associated with a very low failure rate without specific complications. A longer follow-up study is necessary to confirm these promising mid-term clinical results.

References:

1. Ahn JH, Bae TS, Kang KS, Kang SY, Lee SH. Longitudinal tear of the medial meniscus posterior horn in the anterior cruciate ligament-deficient knee significantly influences anterior stability. *Am J Sports Med*. 2011;39(10):2187-2193.
2. Ahn JH, Kim SH, Yoo JC, Wang JH. All-inside suture technique using two posteromedial portals in a medial meniscus posterior horn tear. *Arthroscopy*. 2004;20(1):101-108.
3. Ahn JH, Yoo JC, Lee SH. Posterior horn tears: all-inside suture repair. *Clin Sports Med*. 2012;31(1):113-134.
4. Beaufils P, Verdonk R. The Meniscus. *Springer, Paris*. 2010
5. Charrois O, Ayral X, Beaufils P. [Rapid chondrolysis after arthroscopic external meniscectomy. Apropos of 4 cases]. *Rev Chir Orthop Reparatrice Appar Mot.* 1998;84(1):88-92.
6. Church S, Keating JF. Reconstruction of the anterior cruciate ligament: timing of surgery and the incidence of meniscal tears and degenerative change. *J Bone Joint Surg Br*. 2005;87(12):1639-1642.
7. Crema MD, Roemer FW, Felson DT, Englund M, Wang K, Jarraya M, Nevitt MC, Marra MD, Torner JC, Lewis CE, Guermazi A. Factors associated with meniscal extrusion in knees with or at risk for osteoarthritis: the Multicenter Osteoarthritis study. *Radiology*. 2012;264(2):494-503.
8. Dye SF. Functional morphologic features of the human knee: an evolutionary perspective. *Clin Orthop Relat Res*. 2003;(410):19-24.

9. Granan LP, Bahr R, Lie SA, Engebretsen L. Timing of anterior cruciate ligament reconstructive surgery and risk of cartilage lesions and meniscal tears: a cohort study based on the Norwegian National Knee Ligament Registry. *Am J Sports Med*. 2009;37(5):955-961.
10. Hettrich CM, Dunn WR, Reinke EK; MOON Group, Spindler KP. The rate of subsequent surgery and predictors after anterior cruciate ligament reconstruction: two- and 6-year follow-up results from a multicenter cohort. *Am J Sports Med*. 2013;41(7):1534-1540.
11. Horibe S, Shino K, Nakata K, Maeda A, Nakamura N, Matsumoto N. Second-look arthroscopy after meniscal repair. Review of 132 menisci repaired by an arthroscopic inside-out technique. *J Bone Joint Surg Br*. 1995;77(2):245-249.
12. Ishida K, Kuroda R, Sakai H, Doita M, Kurosaka M, Yoshiya S. Rapid chondrolysis after arthroscopic partial lateral meniscectomy in athletes: a case report. *Knee Surg Sports Traumatol Arthrosc*. 2006;14(12):1266-1269.
13. KAPLAN EB. Surgical approach to the lateral (peroneal) side of the knee joint. *Surg Gynecol Obstet*. 1957;104(3):346-356.
14. Kashihara N, Furumatsu T, Kodama Y, Tanaka T, Ozaki T. Concurrent Lateral Meniscal Repair with Anterior Cruciate Ligament Reconstruction Induces the Extrusion of the Lateral Meniscus: Assessments of Magnetic Resonance Images. *Acta Med Okayama*. 2016;70(6):441-448.
15. LaPrade RF, Wozniczka JK, Stellmaker MP, Wijdicks CA. Analysis of the static function of the popliteus tendon and evaluation of an anatomic reconstruction: the "fifth ligament" of the knee. *Am J Sports Med*. 2010;38(3):543-549.

16. Lee DW, Jang HW, Lee SR, Park JH, Ha JK, Kim JG. Clinical, radiological, and morphological evaluations of posterior horn tears of the lateral meniscus left in situ during anterior cruciate ligament reconstruction. *Am J Sports Med*. 2014;42(2):327-335.

17. Likes RL, Julka A, Aros BC, Pedroza AD, Kaeding CC, Jones GL, Flanigan DC. Meniscal repair with the MaxFire device: a cadaveric study. *Orthop Surg*. 2011;3(4):259-264.

18. Logan M, Watts M, Owen J, Myers P. Meniscal repair in the elite athlete: results of 45 repairs with a minimum 5-year follow-up. *Am J Sports Med*. 2009;37(6):1131-1134.

19. López XP, Tey Pons M, Reina de la Torre F, Verdier LP, Alier Fabregó A, Pavlovich RI, Monllau García JC. [Study of the feasibility of lateral meniscal repair including the popliteal tendon with a knee simulator]. *Acta Ortop Mex*. 2010;24(3):182-186.

20. Mariani PP, Garofalo R, Margheritini F. Chondrolysis after partial lateral meniscectomy in athletes. *Knee Surg Sports Traumatol Arthrosc*. 2008;16(6):574-580.

21. Morgan CD. The "all-inside" meniscus repair. *Arthroscopy*. 1991;7(1):120-125.

22. Noyes FR, Barber-Westin SD. Treatment of meniscus tears during anterior cruciate ligament reconstruction. *Arthroscopy*. 2012;28(1):123-130.

23. Papastergiou SG, Koukoulias NE, Mikalef P, Ziogas E, Voulgaropoulos H. Meniscal tears in the ACL-deficient knee: correlation between meniscal tears and the timing of ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(12):1438-1444.

24. Pasque C, Noyes FR, Gibbons M, Levy M, Grood E. The role of the popliteofibular ligament and the tendon of popliteus in providing stability in the human knee. *J Bone Joint Surg Br*. 2003;85(2):292-298.
25. Peltier A, Lording T, Maubisson L, Ballis R, Neyret P, Lustig S. The role of the meniscotibial ligament in posteromedial rotational knee stability. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(10):2967-2973.
26. Peña E, Calvo B, Martinez MA, Palanca D, Doblaré M. Why lateral meniscectomy is more dangerous than medial meniscectomy. A finite element study. *J Orthop Res*. 2006;24(5):1001-1010.
27. Rochcongar G, Cucurulo T, Ameline T, Potel JF, Dalmay F, Pujol N, Sallé de Chou É, Lutz C, Ehkirch FP, Le Henaff G, Laporte C, Seil R, Gunepin FX, Sonnery-Cottet B; la SFA. Meniscal survival rate after anterior cruciate ligament reconstruction. *Orthop Traumatol Surg Res*. 2015;101(8 Suppl):S323-6.
28. Shelbourne KD, Gray T. Meniscus tears that can be left in situ, with or without trephination or synovial abrasion to stimulate healing. *Sports Med Arthrosc*. 2012;20(2):62-67.
29. Sonnery-Cottet B, Archbold P, Thaunat M, Carnesecchi O, Tostes M, Chambat P. Rapid chondrolysis of the knee after partial lateral meniscectomy in professional athletes. *Knee*. 2014;21(2):504-508.
30. Sonnery-Cottet B, Daggett M, Helito CP, Fayard JM, Thaunat M. Combined anterior cruciate ligament and anterolateral ligament reconstruction. *Arthrosc Tech*. 2016;5(6):e1253-1259.
31. Sonnery-Cottet B, Freychet B, Murphy CG, Pupim BH, Thaunat M. Anterior Cruciate Ligament Reconstruction and Preservation: The Single-

Anteromedial Bundle Biological Augmentation (SAMBBA) Technique. *Arthrosc Tech*. 2014;3(6):e689-693.

32. Stäubli HU, Birrer S. The popliteus tendon and its fascicles at the popliteal hiatus: gross anatomy and functional arthroscopic evaluation with and without anterior cruciate ligament deficiency. *Arthroscopy*. 1990;6(3):209-220.

33. Stephen JM, Halewood C, Kittl C, Bollen SR, Williams A, Amis AA. Posteromedial Meniscocapsular Lesions Increase Tibiofemoral Joint Laxity With Anterior Cruciate Ligament Deficiency, and Their Repair Reduces Laxity. *Am J Sports Med*. 2016;44(2):400-408.

34. Swiontkowski M, Resnick L. Getting a Good Grip Is Key to All-Inside Meniscal Repair. *JBJS Case Connect*. 2015;22;5(3):e61.

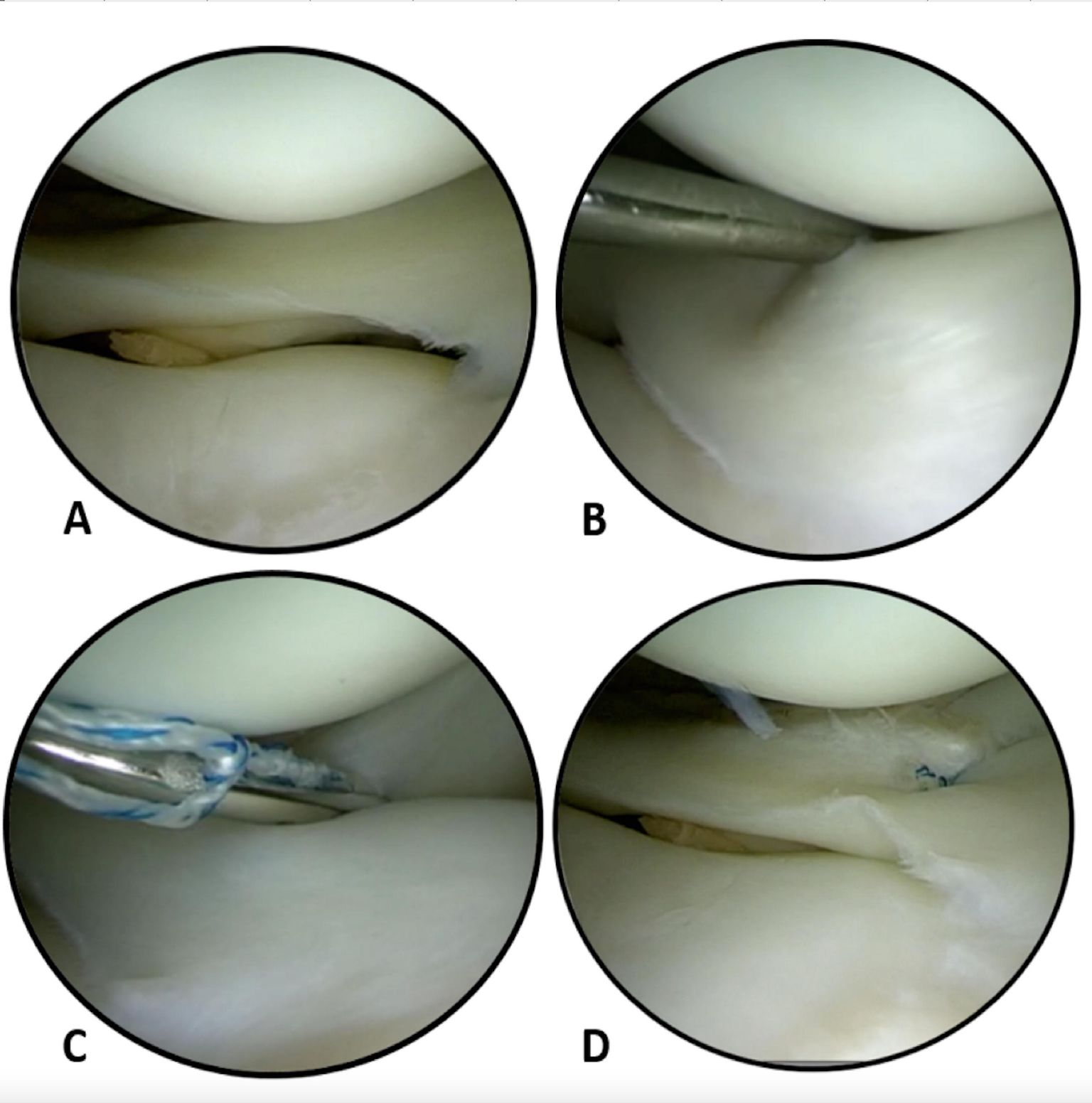
35. Tandogan RN, Taşer O, Kayaalp A, Taşkiran E, Pinar H, Alparslan B, Alturfan A. Analysis of meniscal and chondral lesions accompanying anterior cruciate ligament tears: relationship with age, time from injury, and level of sport. *Knee Surg Sports Traumatol Arthrosc.* 2004;12(4):262-270.

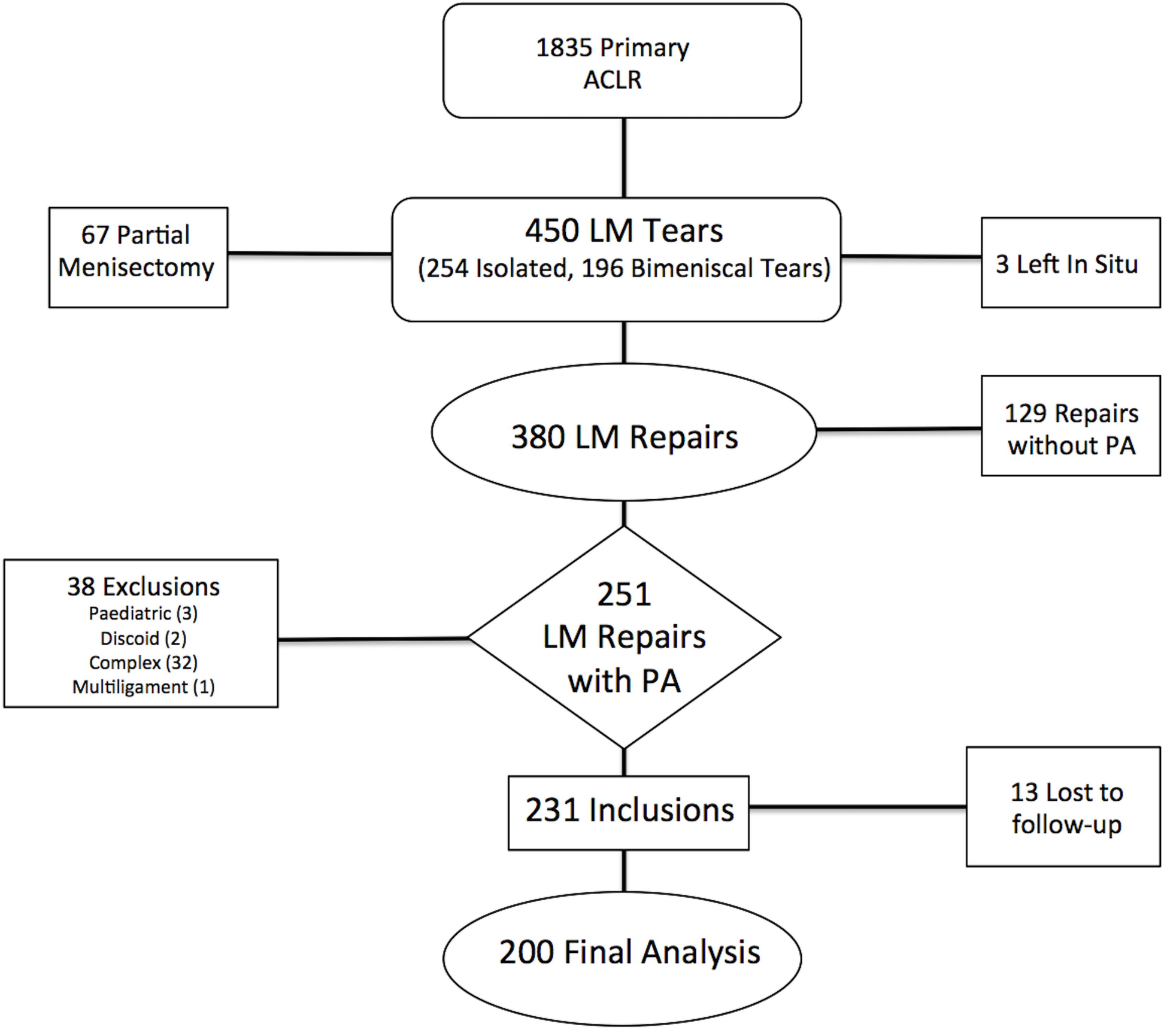
36. Thaunat M, Pioger C, Chatellard R, Conteduca J, Khaleel A, Sonnery-Cottet B. The arcuate ligament revisited: role of the posterolateral structures in providing static stability in the knee joint. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(9):2121-2127.

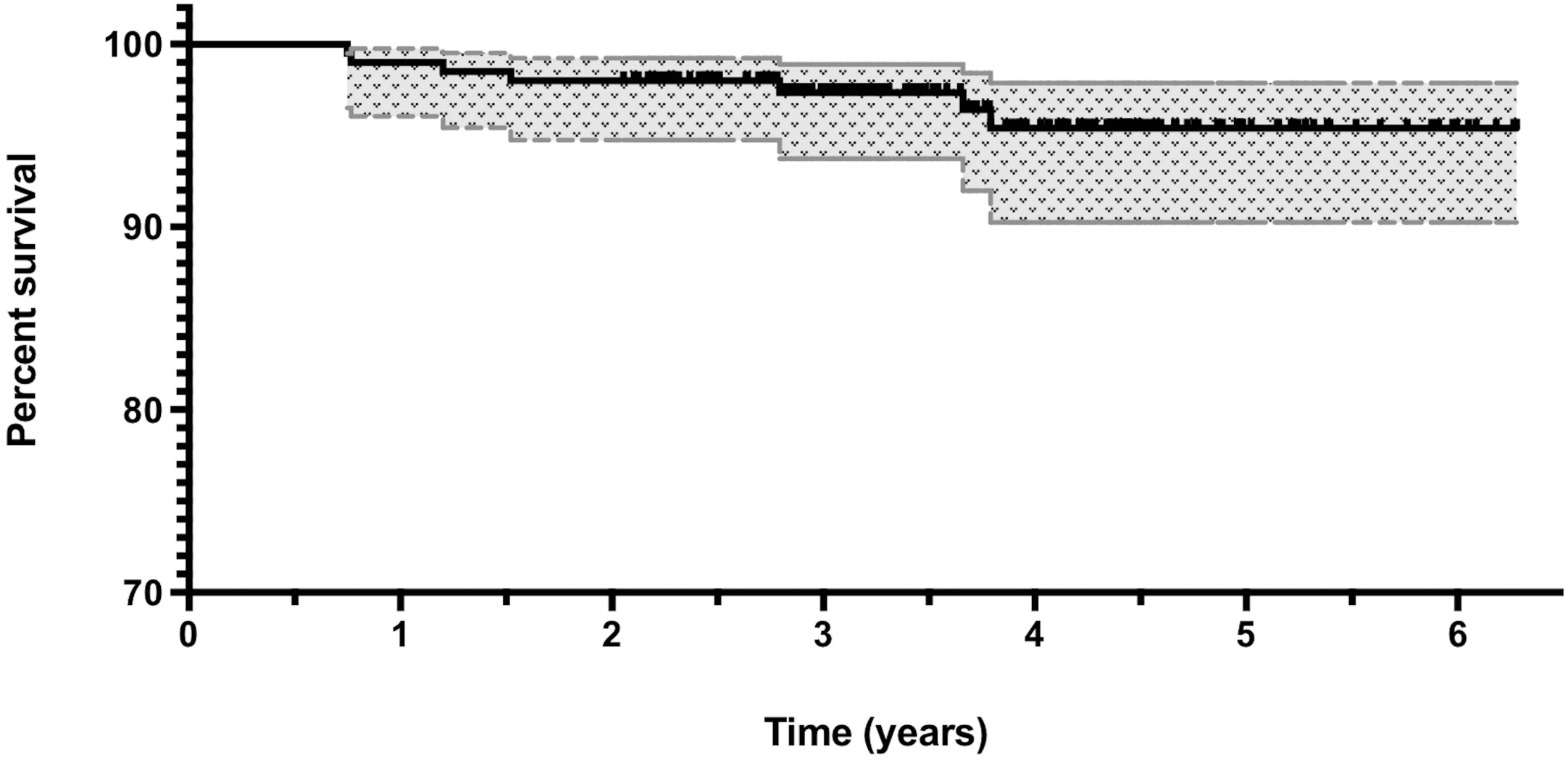
37. Tria AJ Jr, Johnson CD, Zawadsky JP. The popliteus tendon. *J Bone Joint Surg Am*. 1989;71(5):714-716.

38. Uchida R, Mae T, Hiramatsu K, Iuchi R, Kinugasa K, Shino K, Yoshikawa H, Nakata K. Effects of suture site or penetration depth on anchor location in all-inside meniscal repair. *Knee*. 2016;23(6):1024-1028.

570 39. Verdonk PC, Demurie A, Almqvist KF, Veys EM, Verbruggen G, Verdonk
571 R. Transplantation of viable meniscal allograft. Surgical technique. *J Bone*
572 *Joint Surg Am*. 2006;88 Suppl 1 Pt 1:109-118.
573 40. Westermann RW, Wright RW, Spindler KP, Huston LJ; MOON Knee Group,
574 Wolf BR. Meniscal repair with concurrent anterior cruciate ligament
575 reconstruction: operative success and patient outcomes at 6-year follow-up.
576 *Am J Sports Med*. 2014;42(9):2184-2192.
577 41. Xu C, Zhao J. A meta-analysis comparing meniscal repair with meniscectomy
578 in the treatment of meniscal tears: the more meniscus, the better outcome?
579 *Knee Surg Sports Traumatol Arthrosc*. 2015;23(1):164-170.
580 42. Yang JH, Jeong HI, Kim TS, Park SC, Yoon JR. The management of the
581 popliteus hiatus during lateral meniscal transplantation. *Knee*.
582 2012;19(6):959-961.
583


A
B
C
D


1835 Primary ACLR
450 LM Tears (254 Isolated, 196 Bimeniscal Tears)
67 Partial Menisectomy
3 Left In Situ
380 LM Repairs
129 Repairs without PA
251 LM Repairs with PA
38 Exclusions
Paediatric (3)
Discoid (2)
Complex (32)
Multiligament (1)
231 Inclusions
13 Lost to follow-up
200 Final Analysis


Percent survival
100
90
80
70
0
1
2
3
4
5
6
Time (years)