



Excellent medium-term survival of an all-inside tensionable knotted suture device justifies repair of most meniscal tears encountered during reconstructive knee ligament surgery

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Abstract

Purpose All-inside meniscal repair devices have evolved to allow surgeons to undertake complex repairs in a timely and efficient manner. This is advantageous in active patients, where meniscus preservation is critical in preserving joint function and stability. The aim of the study was to evaluate the failure rate of all-inside meniscal repair performed in patients undergoing reconstructive ligament surgery using a particular meniscal repair device.

Methods Patients were identified using a single-site prospectively maintained patient registry. Primary outcome was failure, defined as return to surgery with documented failure of repair. Complication rates and functional scores were also recorded. Patients in whom meniscal repair failure was identified were further assessed, to identify any common features.

Results Over an 8-year period, 323 patients underwent meniscal repair at the time of ligament reconstruction, compared to 244 meniscectomies. Of these, 286 patients underwent repair using an all-inside suture device. One-hundred and twenty-seven repairs were to the medial meniscus only, 124 were lateral, and in 35 patients both menisci were repaired. Follow-up was to a median of 51.5 months. There were 31 (9.7%) failures reported at a median of 22 months post-operatively (IQR 13.5–41.5). Medial repair failures were seen more frequently than lateral (13.6% versus 5.6% OR 2.62 95% CI 1.17–5.88 $p=0.022$). Failure of ACL reconstruction was associated with meniscal repair failure (OR 5.83 95% CI 1.55–21.95 $p=0.0039$). Multi-ligament reconstruction was undertaken in 70/286 patients receiving meniscal repair and was not associated with failure (OR 1.3 95% CI 0.57–2.98 $p=0.51$). Mode number of all-inside sutures used was 3 in both medial and lateral repairs (Range 1–9 lateral; 1–7 medial).

Conclusions All-inside repair is a safe and versatile technique which can be used in the majority of meniscal tears encountered during ligament reconstruction with excellent mid-term success. Failure is seen more commonly in medial sided repairs and with failure of ACL reconstruction.

Level of evidence IV.

Keywords Meniscus · Repair · Ligament reconstruction · All-inside

Introduction

In the acutely injured knee, meniscal tears represent a significant challenge to the treating surgeon. Resection has previously been a reliable procedure, but it is recognised that the consequences of removal of meniscal tissue are long term and potentially catastrophic [9, 18, 26, 27, 31].

Efforts have, therefore, focused on developing a satisfactory method of meniscal repair, to preserve tissue and maintain joint function.

Techniques of meniscal repair may be considered as ‘Outside-In’, ‘Inside-out’ or ‘All-inside’, referring to the direction of passage of sutures within the joint. Inside-out repair techniques, initially described by Henning [12], have previously been considered the ‘gold standard’ of meniscus repair. Outcome data from our own unit have demonstrated this to be a satisfactory technique in combination with anterior cruciate ligament (ACL) reconstruction [19]. Whilst this is a versatile and cost-effective technique it is technically challenging and time consuming, requiring extraarticular dissection of the

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soft tissues on the relevant side of the knee. Far-posterior tears are not adequately addressed with this technique, due to the proximity of the neurovascular structures and the risk of capsular entrapment.

All-inside repair addresses these concerns using specific arthroscopic instrumentation to pass tensionable, self-knotting sutures to the tear, negating the need for an extraarticular dissection [20]. Initial enthusiasm led to the development of many different devices with mixed results [3, 4]. The Fast-Fix Meniscal Repair System (Smith and Nephew Endoscopy, Andover, MA) consists of a curved delivery device and a non-absorbable braided polyester tensionable suture. Ultra Fast-Fix incorporates ULTRABRAID, an ultrahigh molecular weight polyethylene braided suture. Tensionable suture repair has been shown to have a lower failure rate at 2 years than alternative fixation devices in a prospective randomised controlled trial [14].

Despite these advances, meniscectomy is still more frequently performed than repair in the setting of ligament reconstruction [24].

The aim of the study was to evaluate the failure rate of all-inside meniscal repair performed in patients undergoing reconstructive ligament surgery, using a specific meniscal repair device (Ultra Fast-Fix, Smith and Nephew Endoscopy, Andover, MA), and examine factors associated with failure. The hypothesis was that all-inside meniscal repair had acceptable satisfaction and complication rates regardless of tear site and size.

Materials and methods

This study was registered within our institution as a service evaluation and local research approval was granted (Hampshire Hospitals NHS Foundation Trust, Reference: ORTHOEVA05).

A single-centre, prospectively recorded and actively maintained ligament registry was interrogated to identify all patients undergoing concurrent meniscal repair. All patients undergoing ligament reconstruction were reviewed at regular timepoints. Postoperative assessment was at 6 weeks, 3 months, 6 months and yearly thereafter. Laxity using the KT-1000 arthrometer and range-of-motion was assessed independently by a specialist physiotherapist. Functional questionnaires were completed in person or by post. Telephone consultations were reserved only for those instances, where face-to-face review was impractical or undesirable to the patient. Patients reporting persistent knee symptoms interfering with day-to-day activities would undergo further clinical review, MRI scan and arthroscopy if appropriate.

Further case note analysis was performed to obtain key patient, operative and post-operative rehabilitation data. Patients undergoing meniscal transplantation, root repair,

repair techniques other than all-inside, or all-inside repair using a device other than Ultra Fast-Fix were excluded from further analysis. Electronic patient records (EPRs) for all patients were interrogated to capture any further attendances to our centre and surgeries relating to the relevant knee. The fate of patients presenting with symptoms on the ipsilateral knee was determined and recorded. Repair failure was defined at arthroscopy, where an unstable meniscal tear through the same repair bed required treatment.

Patients

All patients undergoing ligament reconstruction at two sites are prospectively entered onto a database which is actively maintained at all review points. Patients complete functional outcome scores including Knee Injury and Osteoarthritis Outcome Score (KOOS), Lysholm and Tegner-Activity scores. These have all been validated in the assessment of knee symptoms following ligament injury and surgery [6, 29]. At clinical review patients undergo examination, range-of-motion assessment and anteroposterior laxity assessment using a KT-1000 arthrometer.

Following arthroscopic confirmation of meniscal injury at the time of ligament reconstruction, an assessment is made as to whether the tear is repairable or not. Multiple considerations affect this decision, including biological factors relating to the patient (smoking, comorbidities, age), social factors (occupation, sporting requirements), tear configuration and chronicity, compartment (medial or lateral) and associated chondral injury. The senior authors (MJR, AJW, SKY) maintain a low threshold to repair injured menisci, in an effort to preserve functionally important meniscal tissue. This may include tears extending into the central zone of the meniscus, particular in lateral injuries. Frankly irreparable tears undergo resection to a stable rim.

Depending on the configuration of the repair, post-operative rehabilitation varies from an early accelerated rehabilitation protocol in smaller tears to a more protective period partially weightbearing in a range-of-motion brace of up to 6 weeks, typically at a range of 0–90°. This reflects the wide variety of tears that are managed with meniscal repair. Patients are often also asked not to perform deep squats for a period of 4-month post repair.

Statistical analysis

Microsoft Excel and SPSS v. 26 were used to generate Kaplan–Meier survival curves. Descriptive statistics were applied to demographic and operative data. Odds ratios (OR) and Fisher's exact test were used to compare groups of categorical data. Confidence Intervals (CIs) were set at 95% and a *p* value of less than 0.05 was considered significant.

Table 1 Demographics of patients undergoing concurrent meniscal repair with ligament reconstruction

Patients	286
Meniscal repairs	321 (35 both menisci)
Mean age (range)	27.0 (9–68)
Male:female	199:87
Left:right	133:153
Medial:lateral	162:159
Mean pre-operative range of motion (range)	
Extension (°)	− 2 (− 25 to + 30)
Flexion (°)	130 (40 to 155)
Primary procedure	
ACL reconstruction	253 (88.5%)
ACL repair/hybrid	9 (3.1%)
Revision ACL	20 (7.0%)
PCL reconstruction	1 (0.3%)
MPFL reconstruction	1 (0.3%)
Additional ligamentous procedure	
Yes	70 (24.5%)
No	216 (75.5%)
Additional non-ligamentous procedure	
Yes	51 (17.8%)
No	235 (82.2%)

Results

Between January 2011 and February 2019 1119 patients were entered onto our ligament registry. Three-hundred and twenty-three (28.9%) patients underwent concurrent meniscal repair, compared to only 244 (21.8%) patients receiving partial meniscectomy. 37 patients undergoing meniscal repair met exclusion criteria, leaving 286 patients for further analysis. Key demographic data is presented in Table 1.

Median follow-up was 51.5 months (interquartile range, IQR 27–74). 269/289 (94%) of patients were followed up to 1 year and 230/286 (80.4%) were followed up to 2 years. All patients were seen face-to-face post operatively at least once and at least 81.2% (573/706) of subsequent clinical assessments were attended in person.

Primary outcomes

Thirty-one patients in this cohort were investigated and treated for meniscal repair failure, giving an overall failure rate of 9.7%. Clinical outcomes are found in Table 2. Failure rates were significantly higher among medial repairs than lateral (13.6% versus 5.6%; OR 2.62, 95% CI 1.17–5.88, $p=0.022$). Median time to failure was 22-month post treatment and there was no difference seen between medial and lateral repairs (Fig. 1). Kaplan–Meier survival analysis is shown in Fig. 2.

Table 2 Meniscal repair failures: characteristics and treatment

	Medial	Lateral	Overall
Meniscal repair failure	22	9	31
Meniscal repair failure rate (%)	13.6% (22/162)	5.6% (9/159)	9.7% (31/321)
Mean age (range)	26.2 (17–48)	27.6 (15–66)	26.6 (15–66)
M:F	14:8	6:3	20:11
Median time to failure in months [IQR]	17.5 [12.3–46.5]	22 [17–37]	22 [13.5–41.5]
Index ligament reconstruction			
ACL	20	7	27
Revision ACL	1	2	3
ACL combined repair/reconstruction	1	0	1
Secondary ligament reconstruction			
Nil	15	7	22
Anterolateral ligament	3	1	4
Posterolateral corner	3	0	3
Medial collateral ligament	0	1	1
Medial patellofemoral ligament	1	0	1
Associated failure of ACL reconstruction	5 (22.7%)	0 (0%)	5 (16.1%)
Treatment of failed meniscus repair			
Partial meniscectomy	22 (100%)	6 (66.7%)	28 (90.3%)
Re-repair of tear	0	2 (22.2%)	2 (6.5%)
Meniscal transplant	0	1 (11.1%)	1 (3.2%)

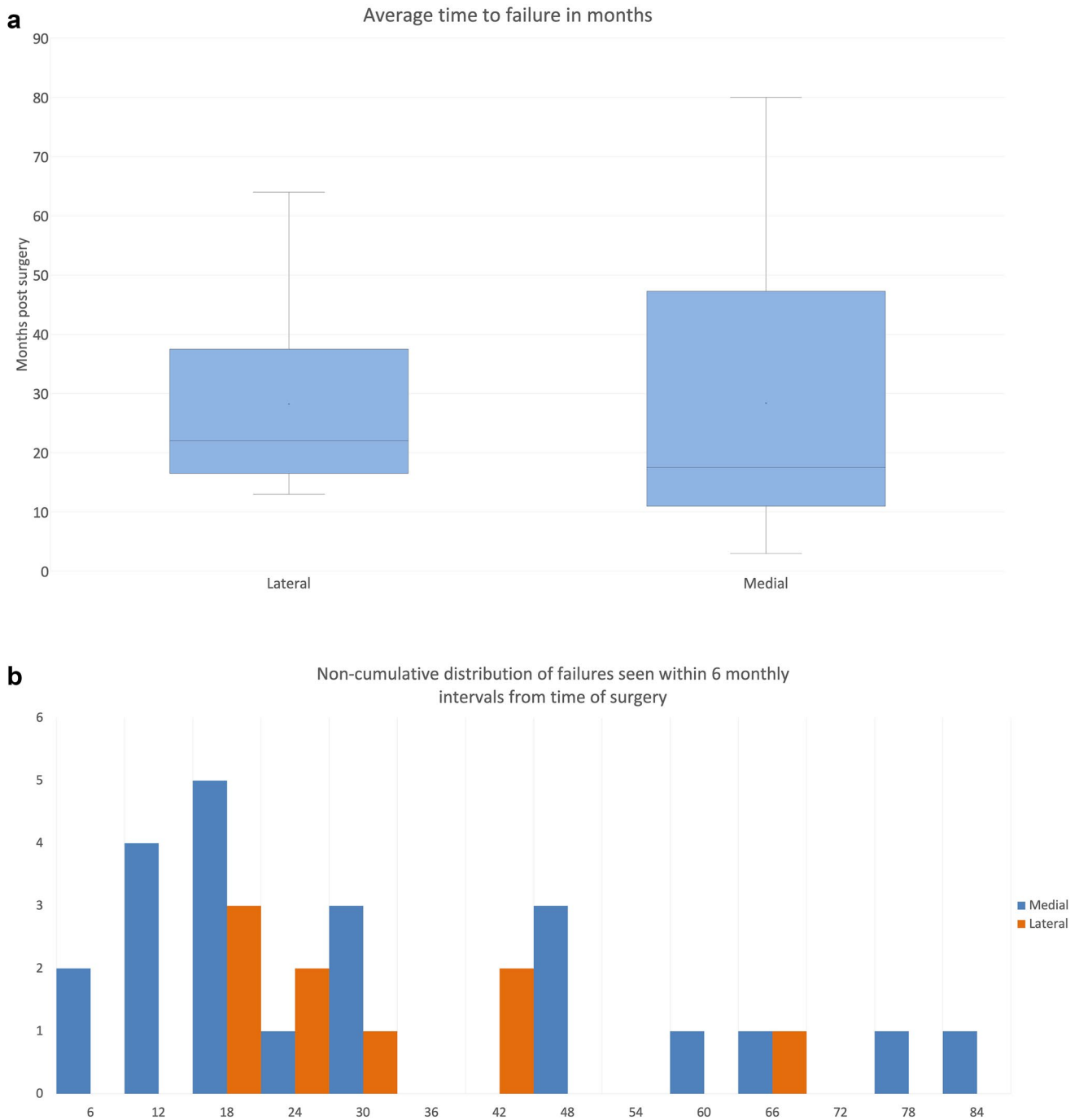


Fig. 1 a, b Time to failure and distribution of failures in medial and lateral meniscus repair

All patients with meniscal repair failures had undergone ACL surgery as their index ligament reconstruction and nine patients had undergone an additional ligamentous procedure. Failure of ACL reconstruction was seen more frequently in the meniscal failure cohort than in those with intact repairs (16.1% versus 2.5%; OR 7.56 95% CI 2.16–26.51 $p=0.0039$).

All medial meniscal repair failures were treated with partial meniscectomy. Lateral meniscal repair failures were treated with partial meniscectomy (66.7%), re-repair (22.2%) or meniscal transplant (11.1%).

In this series, 24 patients underwent further surgery on the same knee unrelated to meniscal failure. There were six revision ACL surgeries, 11 arthroscopies for new tears,

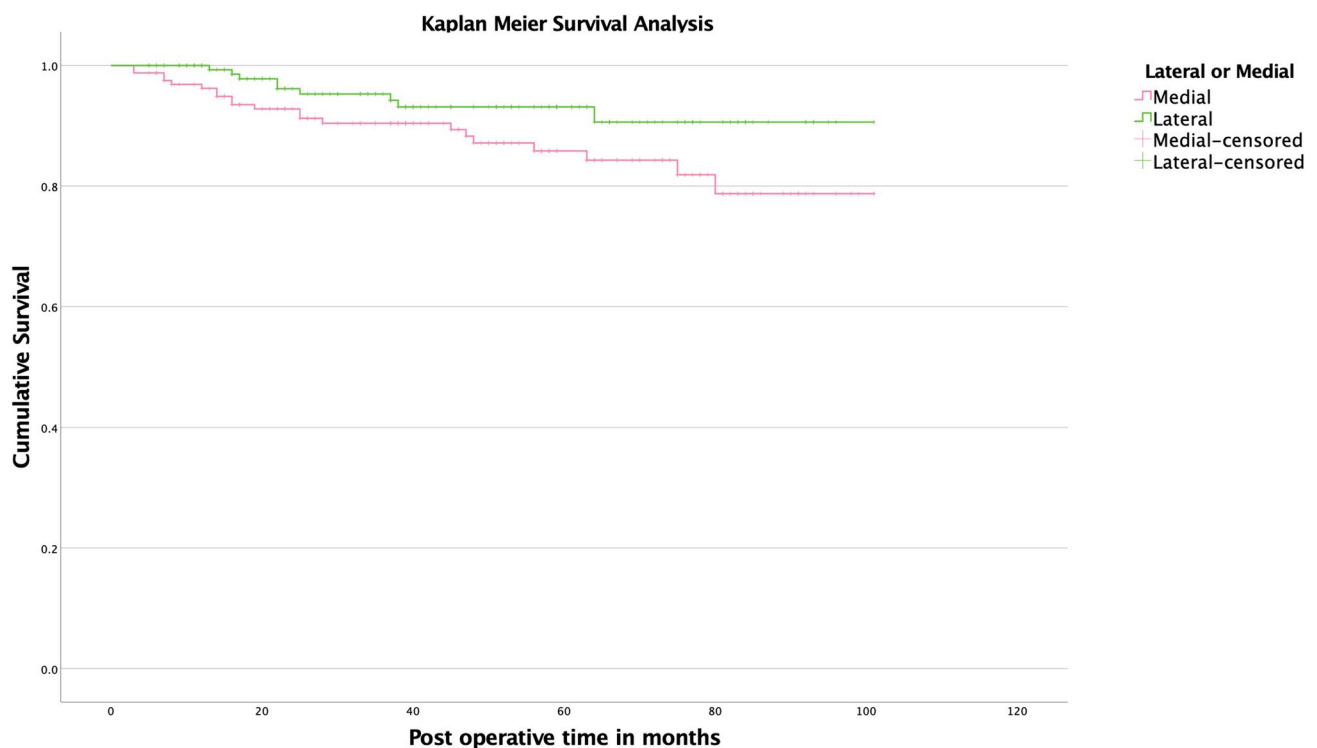


Fig. 2 Kaplan–Meier survivorship curve for medial and lateral meniscal repairs

Table 3 Mean KOOS, Lysholm and Median Tegner-Activity scores at standard timepoints

<i>n</i> =286	Mean KOOS [standard deviation]			Mean lysholm [standard deviation]			Median tegner [range]		
	Pre-op <i>n</i> =230	1 year <i>n</i> =165	2 year <i>n</i> =111	Pre-op <i>n</i> =232	1 year <i>n</i> =164	2 year <i>n</i> =110	Pre-op <i>n</i> =215	1 year <i>n</i> =162	2 year <i>n</i> =105
Repair intact	61.9 [20.5]	87.2 [10.8]	88.2 [11.4]	60.5 [22.8]	87.4 [13.9]	90.1 [11.4]	3 [0–10]	5 [0–10]	5 [1–9]
Repair failed	55.7 [17.9]	78.2 [19.3]	82.0 [18.6]	49.6 [22.4]	75.9 [22.0]	77.7 [19.2]	2.5 [0–9]	4.5 [1–8]	5 [1–9]

cyclops debridement and diagnostic reasons, two further ligament reconstructions, two arthroscopic washouts in the acute phase for haematoma, two arthroscopic arthrolysis and one manipulation under anaesthetic. Including the meniscal failure group, the overall reoperation rate was 55/286 (19.2%). There were no deep infections noted.

Two non-surgical complications were reported. One patient who had undergone medial meniscus repair combined with ACL and posterolateral corner reconstruction suffered with a deep vein thrombosis of the ipsilateral calf. One patient undergoing revision ACL reconstruction combined with anterolateral ligament reconstruction and a lateral meniscus repair suffered a fatal pulmonary embolism 1 week following surgery.

Secondary outcomes

Perioperative KOOS, Lysholm and Tegner-activity scores are presented in Table 3.

Patients experienced improved functional outcome after surgery across KOOS, Lysholm and Tegner-activity scores, regardless of whether or not the meniscus had failed (Fig. 3a, b). In the failure group 17/31 (54.8%) of patients had already been treated for repair failure by the 2-year review timepoint.

Objective laxity assessments using the KT-1000 arthrometer were similar in the repair-intact and repair-failed groups. (mean side–side difference 2.15 mm and 1.88 mm at 6 months, respectively).

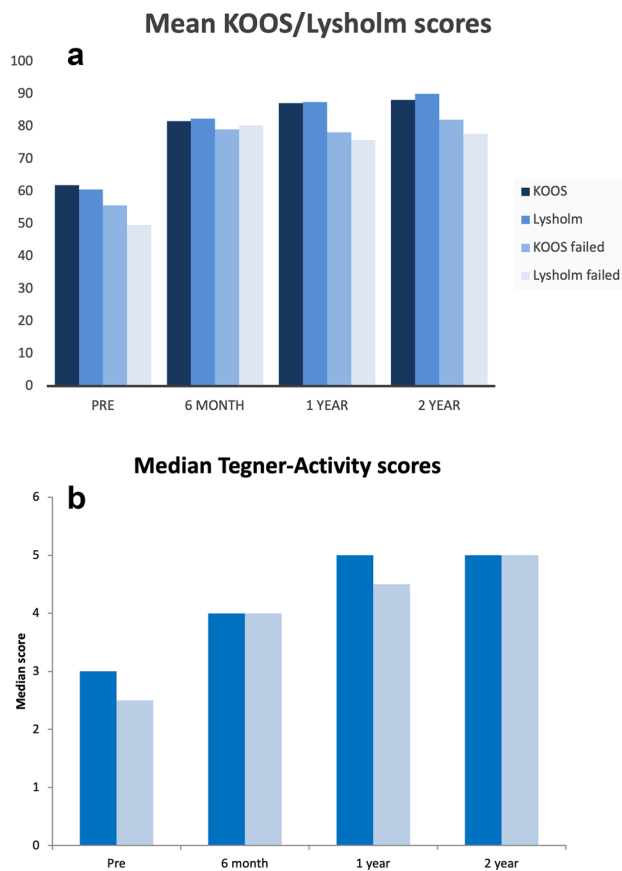


Fig. 3 a, b Comparison of mean KOOS, Lysholm and median Tegner-Activity score in patients with intact and failed (KOOS failed, Lysholm failed, Tegner failed) meniscal repairs

Discussion

The two most important findings of the present study were firstly that satisfactory medium-term outcomes for all-inside meniscus repairs can be achieved using the Ultra Fast-Fix device, and secondly that the majority of meniscal tears encountered during ligament reconstruction can be adequately treated by all-inside meniscal repair. To our knowledge this is the largest series, where clinical outcomes of a single all-inside meniscal repair device in ligament reconstruction have been evaluated.

In a systematic review of 11,711 patients undergoing treatment of meniscus tears at the time of ACL reconstruction between 2001 and 2011, meniscectomy rate was 2–3 times higher than that of meniscal repair [24]. In our series of 567 patients receiving treatment of meniscal tears with ligament reconstruction, more repairs were seen than meniscectomies. Patients who undergo concurrent ACL and meniscectomy are more likely to develop radiographic features of degenerative joint disease compared to meniscal repair and less likely to return to sporting activities [33].

The overall failure rate of 9.7% seen in this group, at an average of 50.1 months, is comparable to other studies [15, 23]. Kotsovolos et al. reported a success rate of 90.2% in a series of 61 meniscal repairs using the Fast-fix system, 62% of whom underwent concurrent ACL reconstruction [16]. Noyes et al. reported on the repair of meniscal tears extending into the avascular zone in patients under the age of 20, with no failures seen in 71 patients [25]. Westermann et al. followed up 286 all-inside and inside-out repairs that had undergone concurrent ACL reconstruction [36]. The failure rate was reported as 14%. The same group performed a systematic review and meta-analysis pooled 1126 patients undergoing meniscus repair at the time of ACL reconstruction and reported failure rates of 10% in inside-out repairs and 16% for all-inside repairs [35]. The lower failure rate seen in our series is attributed to an increased rate of meniscus repair for different tear configurations and, therefore, increased confidence with the arthroscopic technique, use of a single all-inside device compared to the heterogenous group in the pooled data, and a tendency to use more sutures per tear to achieve optimal stability of the repair.

In this study the average number of all-inside meniscal suture devices used was 3 which is typical [5]. In our series between 1 and 9 sutures were required to achieve a stable repair, reflecting the heterogenous group of meniscus tears treated. Length of tear was not routinely measured and did not alter the goal of obtaining a stable meniscus following repair. Length of tear does not determine risk of repair failure [36]. Number of devices required to obtain a stable meniscus is felt by the authors to be a more practical determinant of tear severity, and was not found to be associated with failure in this study. This may be expected, assuming the intended end-point of a stable meniscus was achieved in all patients.

Patients undergoing medial repair were found to be almost three times more likely to fail than those with a lateral repair. The reasons for this are uncertain. Westermann et al. reported similar rates between lateral and medial failures [36]. The outcomes of lateral meniscal repairs are more critical to the overall prognosis of the joint [13, 26, 30]. The overall low failure rate of 5.6% seen in our series justifies the attempted repair of nearly all lateral meniscus tears.

Meniscal repair was previously reserved for peripheral tears only. This is based on cadaveric studies demonstrating a largely avascular central region, accounting for 70–75% of the meniscus [2, 8]. However, several studies have demonstrated satisfactory results with inside-out and all-inside meniscal repair in more central, avascular tears. Reoperation rates between 20 and 38% have been reported [11, 25, 28] with follow-up to 16.8 years in one study [25].

In our series 11 patients received arthroscopy for persistent pain or new unrelated tears. Reporting repair failure based on persistent joint symptoms, or increased signal on

an MRI scan is unreliable. In a study of 23 meniscus repairs evaluated at a mean of 12.9-year follow-up, altered signal was seen in 50% of menisci despite a reported 91% success rate [21]. MRI has separately been shown to only be 60% sensitive in identifying non-healing of meniscus repair [10].

Even in the case of non-healing of a meniscus tear, provided the repair is intact and the meniscal tissue remains stable and functional, we believe this to be a preferable outcome to resection. The presence of stable meniscal tissue following repair is also likely to contribute to overall knee stability [1, 17, 22, 32, 34], particularly important in the context of ligament reconstruction.

Meniscal repair ‘survival’ rate is considered, therefore, to be a more clinically relevant index of success than the meniscal healing, which is a biological process that can only reliably be confirmed at arthroscopy.

Multiple ligament reconstruction was the index procedure in almost a quarter (24.5%) of patients in this cohort. Anterolateral procedures such as anterolateral ligament reconstructions or extraarticular tenodesis ($n=41$) were included, as well as additional collateral or PCL reconstruction ($n=29$). Outcomes of meniscal repair in multi-ligament surgery have not been widely reported. Chahla et al. demonstrated satisfactory outcomes for inside-out meniscal repair in patients undergoing more than one ligament reconstruction with one medial meniscus failure reported in a series of 45 patients [7]. In our series overall failure rate was 12.9% (9/70) in patients undergoing multiple ligament surgery. This was comparable to the 10.2% failure rate seen in patients undergoing single ligament surgery [OR 1.3 95% CI 0.57–2.98 (n.s.)]. Therefore, the need for multiple ligament reconstruction was not associated with an increased likelihood of repair failure and should not deter the treating clinician from undertaking a meniscal repair at the time of surgery.

There are limitations to this study. Despite a policy of long-term multi-disciplinary follow-up and an actively maintained ligament registry, this study will be affected by geographical migration of patients and there is a risk that overall repair failure rate may be underreported as a result. Tear configuration and length was not accounted for and rehabilitation strategy was not standardised. This reflects the wide variety of different tears, patients and injuries treated by our unit. In the context of ligament and concurrent chondral surgery conflicting surgical goals may lead to different rehabilitation procedures. Different repair techniques were not directly compared as our unit reserves inside-out and outside-in techniques for anterior and mid-1/3 tears only. Functional outcomes of meniscectomies were not reviewed and would make an interesting comparison. This unit has previously reported improved favourable outcomes following inside-out repair at the time of ACL reconstruction compared to meniscectomy [19]. The low number of patients with meniscal repair failures makes comparative

statistical analysis difficult, but emphasises the success of the technique.

Conclusion

All-inside meniscus repair using a tensionable knotted suture and curved delivery device is a safe and reproducible technique with excellent rates of survival.

When meniscal tears are identified during ligament reconstruction, repair should be considered a first-line treatment in all patients, recognising the critical role of the meniscus in preserving joint function and stability. Resection should be reserved for patients in whom repair is technically impossible or inappropriate.

Author contributions All authors were involved in manuscript design and writing. ADS, AJF, SKY were involved in data collection and analysis. All surgeries were performed by the senior authors AJW, MJR, SKY.

Compliance with ethical standards

Conflict of interest Smith and Nephew provided financial assistance with research administrative costs. They were not involved in data collection, data analysis, manuscript design or preparation.

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Ethical approval This study was registered as a service evaluation of a device and was granted local research approval within our institution.

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