Tips and Tricks to Optimize Surgical Outcomes After ACL Repair Using Dynamic Intraligamentary Stabilization

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ABSTRACT

Purpose: This paper describes technical difficulties and outcomes for the first 15 patients treated with Dynamic Intraligamentary Stabilization (DIS) for anterior cruciate ligament (ACL) repair.

Methods: The first 15 patients treated with DIS were included. To optimize the inclusion process, a new pre-operative pathway was developed. All intra-operative technical problems were recorded. During the 2-year follow-up period, patient-related outcome measures, return to work, anterior-posterior knee laxity using a Rolimeter and ACL healing as revealed by MRI follow-up scans were recorded.

Results: During 11 DIS procedures, 15 technical problems were encountered. Six were surgeon-related and 9 were material-related. All problems were resolved intra-operatively. Repeat surgery was performed in 4 patients due to arthrofibrosis and in 1 due to a cyclops lesion. The DIS implant was removed in all 5 patients. According to the Tegner score, 7 of 10 (70%) patients returned to the pre-injury level of sporting activity within 6 months. The mean return to work time was 5.4 (SD 3.6) weeks. On MRI, 10 patients showed normal ACL healing (Grade 1) and 3 showed a high repair signal intensity (Grade 2). Although 2 patients showed no signs of ACL healing on MRI (Grade 3), no instability was reported or measured post-operatively or after the DIS implant was removed.

Conclusion: All intra-operative technical problems were resolved and did not lead to conversion to ACL reconstruction. We share tips and tricks that could assist surgeons who are just starting to use the DIS technique.

INTRODUCTION

Anterior cruciate ligament (ACL) rupture is a common injury in active adolescents and young adults. ACL insufficiency can lead to symptomatic instability, secondary meniscal pathologies and degenerative changes.[1]

Surgical treatment with arthroscopic reconstruction of the injured ACL is the gold standard. The overall rate of return to the pre-injury level of sporting activity at 2 years after ACL reconstruction is 63-65%. Although this technique provides satisfactory functional results according to the International Knee Documentation Committee (IKDC) and Lysholm scores, and stability with high levels of patient satisfaction, medium- and long-term results are associated with an increased risk of osteoarthritis and a graft failure rate of 10.3%.[1]

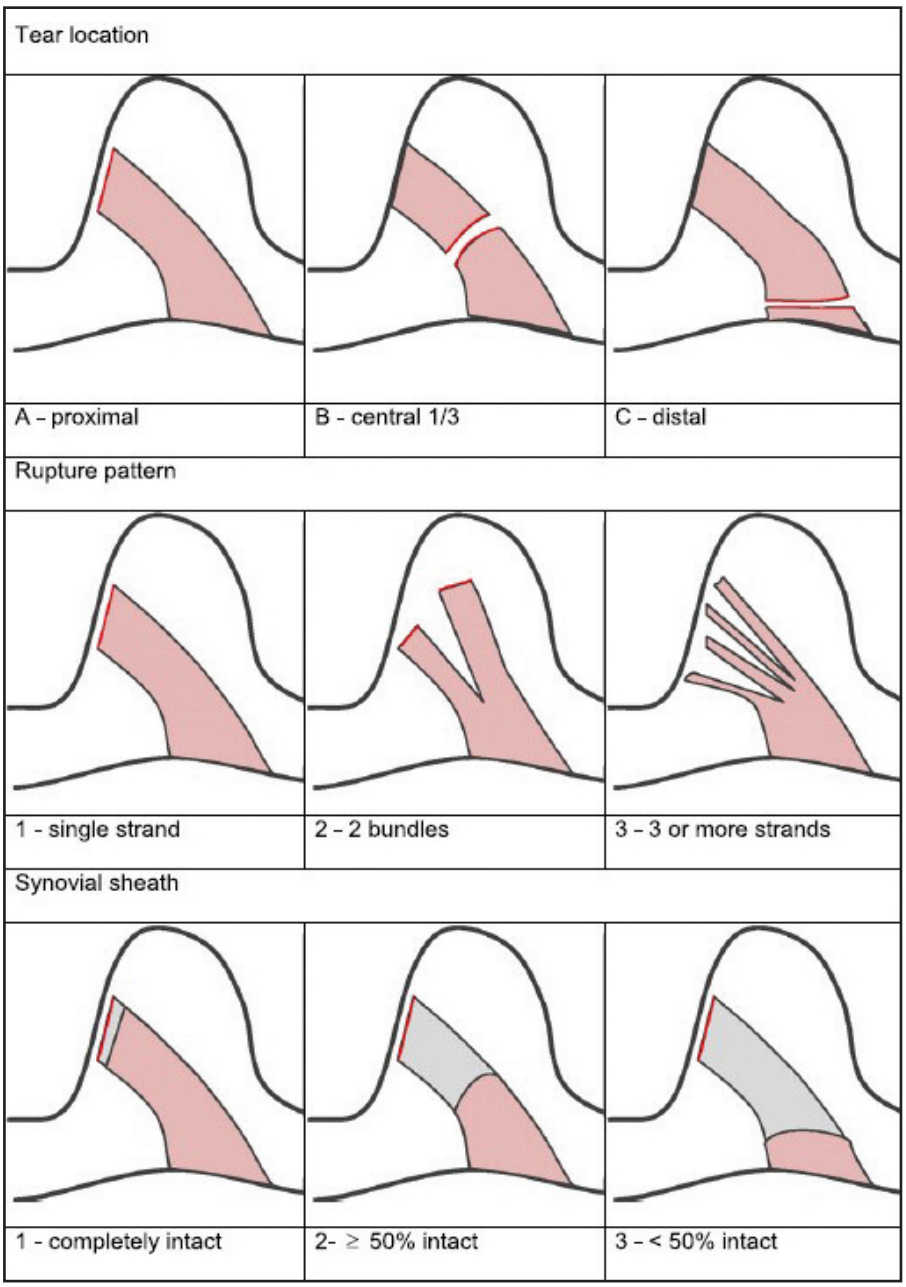

Figure 1. Three-digit ACL rupture classification.[12]

Several studies support the hypothesis that the ruptured ACL possesses capacity for biological healing.[2-4] The healing response of ligamentous tissue after injury is well documented in other human ligaments.[5,6] Several factors compromise the self-healing capacity of the torn ligament, such as a hostile synovial fluid environment, lack of blood supply and post-injury instability due to separation of the ligament stumps.[2,7-10]

The Dynamic Intraligamentary Stabilization DIS technique was developed for the treatment of acute ACL ruptures. The DIS device combines an internal dynamic spring-screw mechanism with a 1.8 mm braided polyethylene anchoring wire to provide continuous stability of the ACL during the self-healing period.[11] Henle et al. reported a case series of 278 patients treated with DIS; 8 patients experienced ACL re-rupture and 3 had insufficient subjective stability of the knee.[12] They concluded that anatomical repositioning, along with DIS and microfracturing, leads to clinically stable healing of the torn ACL in a large majority of patients. Most patients exhibited almost normal knee function, reported excellent satisfaction, and were able to return to their previous levels of sporting activity.

Postoperative MRI can be used to assess ACL healing. De Smet et al. and van der List et al. described the use of postoperative MRIs after ACL repair, but there have been no reports of longitudinal MRI follow-up after DIS.[13,14]

Orthopedic surgeons are familiar with the concept of a learning curve when a new surgical procedure is introduced. When a new surgical technique is introduced in a structured manner, such as by following training courses and performing the surgery on cadavers with the assistance of expert practitioners, this learning curve can be reduced.[15] To date, no previous study has presented tips and tricks for the DIS technique to help reduce the learning curve.

The objective of this paper is to present our technical difficulties and outcomes to help reduce the learning curve and assist surgeons who are starting to use the DIS ACL-preserving technique.

MATERIAL AND METHODS

Study Design

Over a 2-year period, the first 15 patients treated with DIS were included. To optimize the inclusion process, a new pre-operative pathway was developed. All intra-operative technical problems were recorded. During 2 years of follow-up, patient-related outcome measures (PROMs), return to work, anterior-posterior (AP) knee laxity using a Rolimeter and ACL healing on follow-up MRI scans were recorded.

A limit of 3 weeks (21 days) after the rupture has been proposed for carrying out ACL DIS repair.[12] This changes ACL management from a chronic to a (sub)acute problem. A new pathway for patients with a suspected acute ACL rupture had to be developed to enable diagnostic work-up and treatment to take place within 3 weeks after ACL injury. To create awareness of urgent referral, information and lectures were given to the emergency department, general practitioners, physiotherapists and sports physicians. At the appointment desk, a consultation within 2 days was arranged if there was a suspicion of an acute ACL rupture. Cooperation with the radiology department was essential: 1 MRI slot per week was reserved for suspected acute ACL rupture.

Inclusion criteria included an ACL rupture less than 3 weeks old, confirmed on MRI. The study participants had to be between 18 and 60 years old. Exclusion criteria were as follows: posterior cruciate ligament (PCL) injury, lateral collateral ligament (LCL) or grade 2-3 posterolateral corner injury, a fracture that could influence rehabilitation and a non-repairable ACL rupture (intra-operative confirmation). For this study a repairable ACL was defined as a proximal or mid-substance rupture (according to a 3-digit ACL rupture classification; Fig. 1[12]) with good tissue quality and with no gap between the proximal and distal stump after the repair, all confirmed intra-operatively. Before inclusion in the trial, written informed consent was obtained from each study participant, in accordance with ICH-GCP guidelines. The study was approved by the Ethics Committee of Antwerp University Hospital (B300201525523).

The pre-, intra- and post-operative problems encountered were recorded. Pre-injury and post-operative PROMs (Tegner, Lysholm and IKDC scores) were recorded.[16,17] Patient satisfaction using a visual analogue scale (VAS) and return to work and sporting activity were also recorded. Anterior-posterior (AP) knee laxity in 30° flexion (Lachman test) was measured using a Rolimeter.[18] Patients were assessed at 3, 6, 12 and 24 months post-operatively.

All patients were invited to undergo MRI follow-up scans at 3, 6, 12 and 24 months postoperatively. Imaging was performed with a 1.5-T MRI system (Magnetom Aera Tim, Siemens Healthcare, Munich, Germany). Slice encoding for metal artifact reduction (SEMAC) was used to reduce image distortion resulting from the tibial implant.[19] The MRI protocol included the following sequences: sagittal PD-weighted TSE with SEMAC; axial, sagittal, and coronal STIR SEMAC; and coronal T1-weighted TSE sequence with SEMAC. Conventional 1.5- or 3-T MRI was performed if the DIS device had been removed. The MRI scans were assessed by consensus between a radiologist (PVD, with 20 years of experience in musculoskeletal radiology) and an orthopedic surgeon (CH, with 10 years of experience in knee surgery). All images were interpreted with the reviewers blinded to the patient's clinical information. The morphology (position, straight band, and size) and repair signal intensity were assessed on MRI and the ACL repair was graded as follows:[20] Grade 1, well-defined, straight, continuous, normal-sized ACL with signal intensity similar to or only slightly higher than that of the PCL; Grade 2, normal-sized (or slightly thickened) continuous, straight ACL showing a high signal compared to that of the PCL; and Grade 3, an ill-defined, irregular ACL that is thinned or not discernible.

Surgery technique

The following steps were undertaken to reduce the steepness of the learning curve:

- The orthopedic surgeons (CH and LD) followed a training course organized by the manufacturer of the DIS implant (Mathys Ltd Bettlach, Bettlach, Switzerland).
- The first operation was assisted by an orthopedic surgeon who was experienced with the DIS technique.
- For subsequent operations, the surgeons (CH and LD) assisted each other.

A standard anterolateral portal and a slightly larger anteromedial portal were created, followed by a comprehensive examination of the knee joint. Concomitant injuries were treated and the morphology of the ACL rupture was evaluated. The ACL tear type was classified by tear localization, rupture pattern and synovial sheet evaluation (Fig. 1).[12] The surgical technique for DIS was described by Eggli et al.[21] Briefly, the tibial stump of the ACL is positioned against the femoral stump using transosseous PDS 2-0 sutures, thereby restoring the anatomical position of the ACL. Intra-operatively, a knot-pusher through the PDS retaining sutures can be used to check if the distal stump is fully reduced to the proximal stump. If the ACL is not repairable, the operation can be converted to reconstruction during the same procedure. In addition to the technique described by Eggli et al., we used lasso sutures (FiberLink™, Arthrex®, Naples, FL) on a suture-passer (Scorpion, Arthrex®)[22] to reduce the ACL stump in case of a multiple or mid-bundle rupture. A maximum of 3 lasso sutures fit in the femoral tunnel. At the femoral footprint, microfracturing was carried out. A tibial tunnel was drilled, exiting posterolateral to the tibial footprint to prevent damage to the ACL's blood and nerve supply. The spring-screw implant (Ligamys®, Mathys Ltd Bettlach, Bettlach, Switzerland) was placed in the tibial tunnel. The femoral tunnel was drilled at the origin of the ACL. The ACL was reinforced with a strong polyethylene cord which was fixed on the femoral side with a button. With the knee in extension, the reinforcement cord was fixed on the tibial side in the spring-screw implant with a force of 50-80 N, depending on the sex of the patient.

Post-operative treatment consisted of a schematic training plan with a physiotherapist, following the Ligamys® protocol.[23]

RESULTS

Demographics of the study population

Two surgeons (CH and LD) performed the DIS operation in 15 patients between October 7, 2014, and September 21, 2016. The male-to-female ratio was 6:9. The mean (SD) age was 32.8 (9) years. The right-to-left knee ratio was 6:9. The mean (SD) injury-to-surgery

Table I
Clinical scores, Lachman anterior-posterior difference (mm) between the DIS repair and the contralateral knee, and patient satisfaction

Outcome measure	Pre-injury	Pre-operative	3 months	6 months	12 months	24 months
Tegner score	4.9 (2.7)	/	3.1 (2.1)	5.4 (2.6)	4.9 (2.6)	5.1 (2.5)
Lysholm score	96.3 (11.6)	/	66 (21.8)	88.7 (7.4)	94.1 (7.5)	96.1 (5.0)
IKDC score	99.0 (1.8)	/	0.2 (2.0)	79.4 (15.7)	88.4 (9.7)	93.9 (4.4)
Lachman difference (mm)	/	4 (2.4)	0.2 (2.0)	0.7 (1.4)	0 (1.5)	0.4 (1.7)
Satisfaction (VAS)	/	/	8.4 (1.6)	8.4 (1.4)	9.2 (0.7)	9.3 (0.8)

Values represent means (standard deviation). DIS, Dynamic Intraligamentary Stabilization; IKDC, International Knee Documentation Committee; VAS, Visual Analogue Scale

interval was 17 (2) days. Eight patients showed additional lesions of the injured knee. Eight patients had medial collateral ligament (MCL) lesions, and 3 of them were treated with *Internal*Brace™ (Arthrex).[24] One patient had a type 1 strain of the LCL which was treated conservatively. In 2 patients, the lateral meniscus was sutured and in 1 patient the medial meniscus was partially resected. In 11 of the 15 patients, no additional procedures were performed.

Rupture classification

Seven patients (46.7%) had an A.1.1 rupture (proximal third, single strand, completely intact synovial sheath), 1 (6.7%) had an A.1.3 rupture (proximal third, single strand, <50% intact synovial sheath), 4 (26.7%) had an A.2.1 rupture (proximal third, 2 bundles, completely intact synovial sheath), 1 (6.7%) had an A.3.1 rupture (proximal third, 3 or more strands, completely intact synovial sheath) and 2 (13.3%) had a B.3.1 rupture (central third, 3 or more strands, completely intact synovial sheath)(Fig. 1).[25] Lasso sutures were used for the B.3.1. ruptures and for a A.2.1. rupture, after the PDS sutures broke out.

Post-operative data

Clinical scores (Tegner, Lysholm and IKDC scores), the AP difference between healthy and injured knees, and patient satisfaction (VAS) were recorded. Patients were asked what the score was before injury and after 3, 6, 12 and 24 months (Table I).

With the Tegner score as a guide, 7 of 10 patients (70%) returned to the pre-injury level of sporting activity after 6 months, 10 of 13 patients (76.9%) after 1 year and 11 of 14 (78.6%) after 2 years. The mean (SD) return to work time was 5.4 weeks (3.6).

Problems encountered intra-operatively

During 11 DIS procedures, 15 technical problems were encountered. Six were surgeon-related and 9 were material-related. All problems were solved intraoperatively.

During 5 procedures, we experienced a malfunction of the suturing forceps and were not able to pass the resorbable PDS 2-0 sutures through the ACL stump. These problems were not encountered with second-generation suturing forceps.

In 2 procedures, the shuttle suture broke while the polyethylene cord was being passed through the femoral tunnel. The broken shuttle suture was replaced with a stronger shuttle suture.

During 1 procedure, the spring-screw implant fell apart while the guide wire was being retrieved. A new implant was placed, but this also fell apart. We put the spring back in the second implant and it did not fall apart again. The manufacturer of the implant addressed this problem as a production error. We did not encounter this problem subsequently.

Leading the polyethylene cord distally caused problems during 2 procedures at the ACL stump site. The polyethylene cord became entangled with the ACL stump or the PDS 2-0 sutures. A new shuttle suture was tied to 1 of the shuttle suture ends distally and passed proximally through the femoral tunnel, after which the polyethylene cord was transported distally with no problems.

During 1 of the procedures, the clamping cone broke off while it was being secured to the spring-screw implant. Afterwards, we noticed that we had not placed the clamping cone in-line with the spring-screw implant. It is important to place the clamping cone exactly in-line with the spring-screw implant.

We also would like to emphasize the importance of maintaining adequate tension on the PDS retaining sutures while the polyethylene cord is passed through the femoral tunnel and fixated. After the procedure was finished, the final arthroscopic check showed an attenuated ACL; the PDS sutures were not properly tensioned and therefore the ACL stump was not tight to its origin. We had to loosen the clamping cone and the femoral button with the polyethylene cord to be able to tension the retaining sutures adequately. With this maneuver, we achieved adequate tension on the ACL. During re-fixation with the clamping cone, the polyethylene cord broke. While a new polyethylene cord was being transported through the femoral tunnel, the PDS sutures in the ACL stump broke out. When we replaced the PDS retaining sutures in the ACL stump, the sutures did not have enough grip to reduce the stump. Through the use of lasso sutures, we managed to reduce the ACL stump to its origin at the correct tension.

To prevent interposing tissue or tissue bridges from the medial arthroscopic portal between the different sutures, we make a larger medial arthroscopic portal, place the suturing forceps around the threads outside the portal, and pass it through the portal intra-articularly. No interposing tissue should be encountered (Fig. 2). Tips and tricks are summarized in Table II.

Problems encountered post-operatively

Postoperatively, 4 (26.7%) patients developed a jumper's knee within the first 3 months during rehabilitation. Adaptation of physiotherapy and anti-inflammatory drugs resolved these problems, and a normal rehabilitation program could be resumed thereafter.

Four patients (26.7%) developed arthrofibrosis, confirmed on MRI. They underwent arthrofibrolysis and DIS removal at, respectively, 2, 4, 6 and 8 months postoperatively. All 4 patients were women, and 2 of these 4 patients were slender. They both felt immediate relief after arthrofibrolysis and removal of the DIS, and stated that they had regained their "natural knee movement", which they had lost since the primary DIS procedure.

One patient (6.7%) developed a cyclops lesion. Arthroscopy showed an intact ACL and the cyclops lesion, which was removed.

In all 5 patients who had a repeat surgery, the DIS implant was removed as well. AP knee laxity did not increase after the implant was removed.

There were no ACL re-ruptures after a 2-year follow-up. No patients reported instability postoperatively, including the patients who underwent removal of the DIS implant.

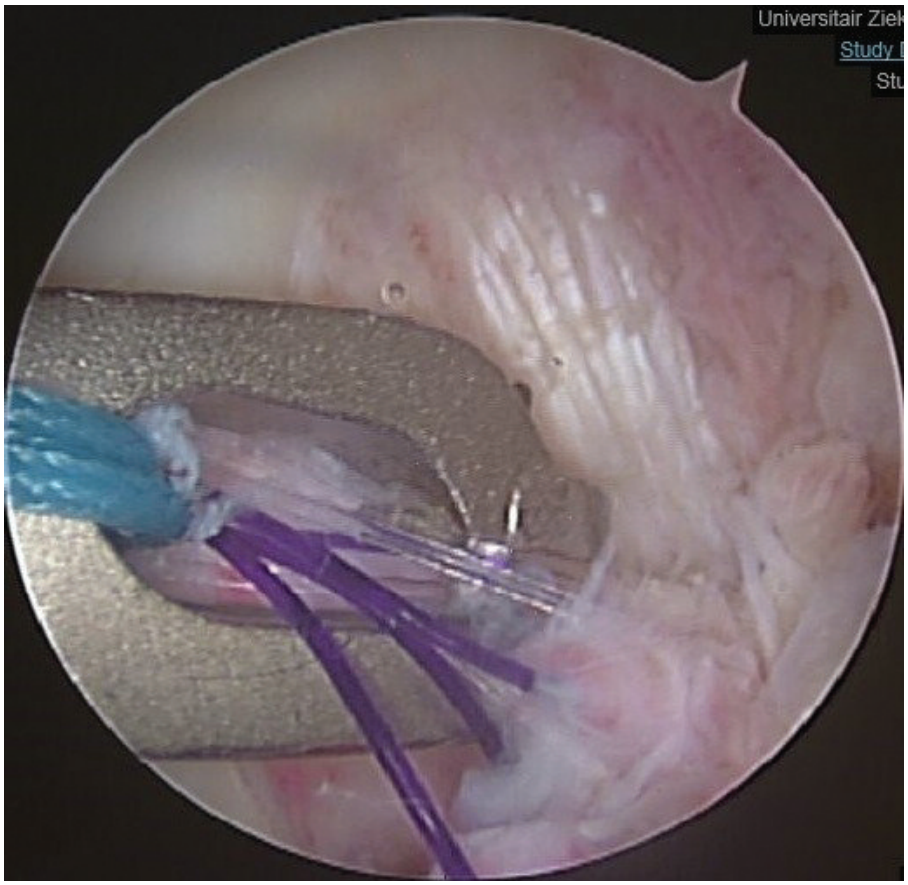

Figure 2. Suture management with the suturing forceps: no interposing tissue between the different sutures.

MRI

A total of 47 MRI studies for the 15 patients were available for review (3 months, n=8; 6 months, n=12; 12 months, n=13; and 24 months, n=14). Thirty-eight MRI examinations were performed using the SEMAC MRI protocol at 1.5-T and 8 examinations were performed using a conventional protocol at 3-T if the spring-screw implant had been removed.

At 24 months postoperatively, 9 patients showed normal ACL healing (Grade 1) and 3 showed persistent high repair signal intensity (Grade 2) on MRI. Two patients showed no signs of ACL healing on MRI (Grade 3). One patient refused to undergo MRI

Table II
Tips and tricks for surgeons who are just starting with DIS

Preoperative	Develop a preoperative patient pathway to enable a diagnostic work-up and treatment within three weeks after the ACL injury.
ACL stump	Using a knot-pusher through the PDS retaining sutures, check whether the distal stump is fully reduced to the proximal stump (Fig. 6). If the ACL stump cannot be properly reduced using the PDS 2.0 sutures, or if it is a multilacerated rupture, lasso sutures can be used.
Suture management	Make a larger medial arthroscopic portal and check with the suturing forceps around the threads through the medial portal for interposing tissue or tissue bridges (Fig. 2).
Shuttle sutures	Use strong shuttle sutures to prevent breakage of the shuttle suture in the femoral tunnel.
Implant tension	Do not exceed 60 N tension on the spring-screw implant for women; we aim for 50 N in slender or smaller women.
MRI	Absence of healing on MRI should be interpreted with caution, and correlation with clinical findings is necessary.

ACL, anterior cruciate ligament; PDS, polydioxanone suture

Table III
Intra-operative ACL rupture type [12] and post-operative ACL healing on MRI

Patient No.	ACL rupture type	Post-operative ACL healing on MRI			
	Intra-operative	3 months	6 months	12 months	24 months
1	A.1.1.	3	3	3	3
2	A.1.3.		2	2	2
3	A.1.1.		2	1	1
4	A.1.1.	2		1	1
5	A.3.1.	2		2	2
6	A.1.1.	3	2	1	1
7	A.2.1.			3	3
8	A.1.1.		2	1	1
9	A.2.1.		2	1	1
10	B.3.1.	3	2	2	1
11	A.2.1.		2		2
12	A.1.1.	2	2	1	1
13	B.3.1.	2	2	1	
14	A.1.1.				1
15	A.1.1.	2	1	1	1

ACL healing was graded as follows:[20] Grade 1, well-defined, straight, continuous, normal-sized ACL with signal intensity similar to or only slightly higher than that of the PCL; Grade 2, normal-sized (or slightly thickened) continuous, straight ACL showing a high signal compared to that of the PCL; and Grade 3, an ill-defined, irregular ACL that is thinned or not discernible. ACL, anterior cruciate ligament; PCL, posterior cruciate ligament

follow-up at 24 months, but demonstrated a healed ACL repair at 12 months. Based on the MRI findings, remodeling of the ACL repair was most evident between 6 and 12 months postoperatively. The healing status remained unchanged between 12 and 24 months postoperatively, except for 1 patient. Findings are summarized in Table III and Figs. 3-5.

DISCUSSION

We present the technical difficulties and outcomes for the first 15 patients treated with DIS with follow-up over 2 years, as well as tips and tricks to optimize the surgical outcomes of ACL repair using the DIS technique.

Starting a new technique involves "start-up problems". Organizing a new patient pathway, dealing with "new" arthroscopic instruments and suture management, postoperative problems and MRI interpretation after ACL repair are examples of the issues we encountered. This paper provides tips and tricks that could assist surgeons who are just starting to use this ACL-preserving technique.

Setting up a new pathway for patients with a suspected acute ACL rupture to allow diagnostic work-up and treatment to take place within 3 weeks after the injury is important when introducing DIS. Making specific agreements with the outpatient clinic, radiology department and operation theatre is key to enable surgery to take place within 3 weeks after injury. General practitioners, physiotherapists and emergency physicians should be informed, as the management of a ruptured ACL is changing from a chronic lesion to a sub-acute lesion. Referred patients with suspected acute ACL rupture were evaluated in our outpatient clinic within 2 days. To ensure rapid access to an MRI, a weekly slot was made available to evaluate acute ACL ruptures. With these prior arrangements, we managed to treat acute ACL ruptures within 3 weeks of injury, but

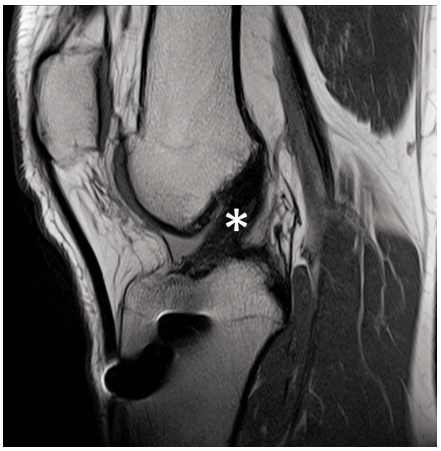

Figure 3. Sagittal proton-density-weighted MRI images with use of slice encoding for metal artefact reduction.[19] Grade 1;[20] normal anterior cruciate ligament (ACL) healing, 2 years after a proximal single bundle ACL repair. * = ACL

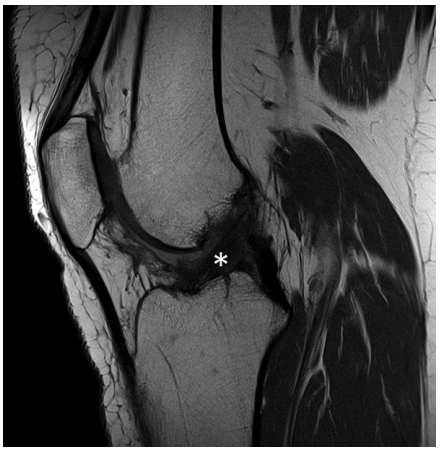

Figure 4. Sagittal proton density weighted MRI image. Grade 2;[20] the anterior cruciate ligament (ACL) is of normal size but the proximal part of the ACL has a higher signal compared to that of the PCL, 2 years after a proximal double-bundle ACL repair. * = ACL

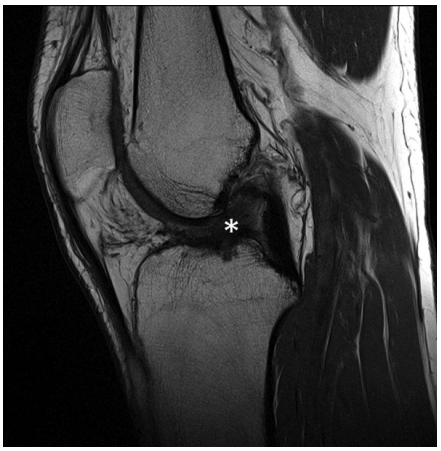

Figure 5. Sagittal proton density weighted MRI image. Grade 3;[20] the anterior cruciate ligament (ACL) is ill-defined, irregular, and there is no sign of healing 2 years after a proximal single-bundle ACL repair. * = ACL

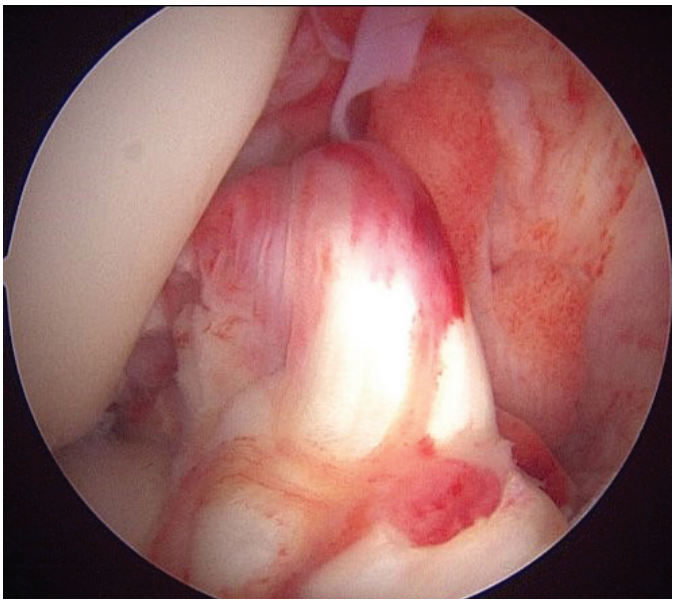
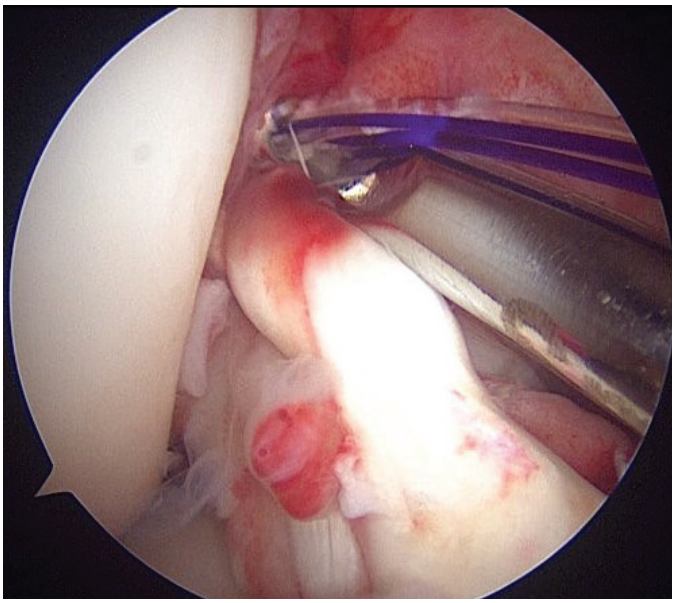

Figure 6. (a) Right knee, arthroscopic view of the ruptured anterior cruciate ligament (ACL). The distal bundle is not in contact with the proximal bundle. (b) Right knee, arthroscopic view of the ruptured anterior cruciate ligament (ACL). With a knot-pusher through the polydioxanone retaining sutures, the reduction of the ACL stump can be assessed. A gap between the proximal and distal stump should not be accepted.

were not able to treat most ACL ruptures within this time-frame. Patient delay and delay by referring doctors were among the reasons why most ACL ruptures were treated after 3 weeks.

Murray et al. reported the necessity of a stable fibrin-platelet clot between the ruptured ends of the ACL within which stable scar tissue can form.[26] If the distal stump is not fully in contact with its proximal counterpart, the synovial fluid will wash out the fibrin-platelet clot and the ACL will not heal. Intra-operatively, a knot-pusher through the PDS retaining sutures can be used to check whether the distal stump is fully reduced to the proximal stump (Fig. 6). It is advisable to perform this maneuver before the 10mm DIS tibial tunnel is created. If the stump cannot be reduced properly, the operation can be converted to reconstruction during the same procedure and the tibial tunnel can be adjusted to the correct size for reconstruction.

In addition to the standard DIS technique, we used lasso sutures (FiberLink™, Arthrex®) on a suture-passer (Scorpion, Arthrex®)[22] if the PDS sutures could not fully reduce the ACL. With the lasso sutures, more traction can be applied to the ACL stump and, in the case of a multiple-bundle rupture, the lasso can reduce several bundles, whereas the PDS wires can break out of smaller bundles.

One of the problems encountered intra-operatively was entangling of the 4 to 6 sutures from the arthroscopic portal due to a tissue bridge. Shoulder surgeons are already more familiar with suture management; for most knee surgeons, this is a new action that has to be performed to prevent tissue bridges between the different sutures (Fig. 2).

A delay of 3 weeks (21 days) between the rupture and DIS surgery has been proposed.[12] In other ACL repair techniques,[27,28] the ACL can be repaired up to 3 months after the rupture. Van der List et al. reported that primary repair was more likely to be possible in older patients and patients with a lower BMI, and when surgery was performed within 4 weeks of injury.[29]

Nowadays, we perform DIS up to 4 weeks after rupture. We believe that this period can be even longer, as long as the ACL stump is ruptured proximally, shows good tissue quality and is able to make full contact with the proximal stump.

In this study, 2 patients with a mid-bundle rupture were treated with DIS. One of these patients developed arthrofibrosis and an arthroscopic arthrofibrolysis was performed. Evangelopoulos et al.[30] reported high complication rates (78.8%) for mid-substance ACL tears treated with DIS. However, the 2 patients with a mid-bundle rupture in this study showed a healed (grade 1) ACL on MRI (Table III). Mid-substance ACL ruptures and a high pre-injury sporting activity level have been reported to be predictors of an inferior outcome.[31] Therefore, we now no longer perform DIS on mid-bundle ruptures.

Overall complication rates of up to 57.8%[32] have been reported with the DIS procedure. Haberli et al.[33] reported a repeat surgery rate of 48.2% in 190 patients after DIS ACL repair. Of these repeat surgeries, 5.8% were scar tissue debridement with hardware removal due to range-of-motion deficits. In this study, 5 of the 15 patients had a repeat surgery within the 2-year follow-up period. All the patients who developed decreased knee function and arthrofibrosis were women. Two of these 4 patients felt immediate relief after arthrofibrolysis combined with removal of the DIS implant and expressed that they had regained their "natural knee movement". We believe that, especially for slender women, extra attention should be given to the tension on the DIS implant. The DIS manufacturer recommends that the tension on the DIS implant should not exceed 60 N for women, while for slender women we prefer not to exceed 50 N. Patients should be informed pre-operatively about the possibility of repeat surgery.

The literature on return to work after ACL reconstruction or repair is not extensive. Haberli et al.,[33] in a matched study between DIS and reconstruction, reported that DIS patients benefited from a reduction in absence from work of almost 1 month compared with ACL reconstruction patients. This difference is probably related to the early timing of surgery that is recommended for DIS. In this study, the mean return to work time was 5.4 weeks (SD 3.6). Compared to reconstruction, there is no comorbidity

due to graft harvest and since the proprioceptors of the ACL are also preserved, this could hypothetically lead to a faster rehabilitation and return to work.

On MRI, the healing process of the repaired ACL is different compared to the "ligamentisation" phase of ACL reconstruction. Van der List et al. reported that postoperative MRI accurately predicted re-rupture of ACLs that had undergone a primary repair. Furthermore, the repaired ligament can be expected to be hyperintense within the first year, while the signal becomes similar to that of an intact PCL after 2 years.[14] Based on the MRI findings in this study, remodeling of the ACL repair was most evident between 6 and 12 months postoperatively. The healing status remained unchanged between 12 and 24 months postoperatively, except for 1 patient. Although patients may demonstrate signs of ACL healing on MRI following repair, persistently high repair signal intensity can be seen for more than 12 months postoperatively in clinically stable knees. Absence of healing on MRI should be interpreted with caution, and correlation with clinical findings is necessary.[34]

A systematic review of DIS concludes that there is sufficient evidence to support DIS repair as possibly an effective modality for the treatment of acute proximal tears of the ACL. Overall, there is evidence to suggest that ACL repair should be included in the decision tree for individualized treatment planning. The best outcomes will be achieved with the selection of suitable patients.[35]

CONCLUSION

In our experience with Dynamic Intraligamentary Stabilization (DIS) for ACL repair, all intra-operative technical problems were resolved and did not require conversion to ACL reconstruction. The tips and tricks presented here could assist surgeons who are just starting to use the DIS technique. STI

AUTHORS' DISCLOSURES

LD is a member of the speakers' bureau for Mathys Ltd Bettlach (Bettlach, Switzerland), but did not receive any financial support for this study. The other authors declare that there are no conflicts of interest.

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