

Outcomes of arthroscopic repair using the all-inside inter-leaf vertical suture technique for horizontal meniscal tears sustained in sports

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Abstract

The aim of the study was to evaluate the outcomes of arthroscopic repair using the all-inside inter-leaf vertical suture arthroscopic technique for sports-related horizontal meniscal tears.

The inter-leaf vertical suture procedure was performed to repair sports-related horizontal tears in the middle and posterior segments of the medial (11 cases) and lateral (2 cases) menisci in 13 patients (mean age: 30 ± 14 years). Pre- and post-operative Barrett criteria, Lysholm scores, and patient ability to resume sports were assessed. Magnetic resonance imaging (MRI) grades and signal intensity changes near the joint capsule were evaluated in the 9 cases among which pre- and post-operative MRI images were available.

All Barrett criteria items were negative following surgery; Lysholm scores increased from 70.2 ± 13.1 before surgery to 98.9 ± 2.64 after surgery ($P < .01$). All patients were able to resume their sport. Preoperative MRI grade of tears was 3 for all patients; postoperative MRI grades were 1 in 3 cases, 2 in 4 cases, and 3 in 2 cases ($P < .05$). Importantly, MRI signal intensity at the repaired menisci near the joint capsule was reduced in 8 of these 9 cases postoperatively.

The inter-leaf vertical suture procedure is associated with good outcomes for horizontal tears in the middle and posterior segments of the medial and lateral menisci. The procedure is useful and convenient.

Abbreviations: ACLR = anterior cruciate ligament reconstruction, FF = Fast-Fix, ICRS = International Cartilage Repair Society, IL = inferior leaflet, MRI = magnetic resonance imaging, PCLR = posterior cruciate ligament reconstruction, SL = superior leaflet.

Keywords: all-inside suture, arthroscopy, horizontal tear, knee, meniscus repair

1. Introduction

The knee meniscus acts as a shock absorber for the tibiofemoral joint.^[1] It also contributes to improving joint congruency, proprioception, and synovial fluid spread over the joint surface.^[2–4] Meniscal injuries may occur during sports involving

excessive knee joint rotational movements^[5] and may occur concurrently with ligament injuries.^[6] Partial resection of the damaged meniscus can lead to rapid cartilage degeneration and increase the risk of osteoarthritis.^[7–11] The progression of osteoarthritis following meniscectomy is more apparent in active patients.^[12] Hence, it is necessary to optimally repair the damaged meniscus and preserve its function, especially in patients with an active lifestyle.^[13]

Meniscal injuries are classified as longitudinal, radial, and horizontal tears, with the latter being the most frequent.^[14] About 22.5% of isolated meniscal injuries in young active patients are horizontal tears.^[15] Horizontal tears are commonly treated by single-leaflet resection^[16] or resection of both leaflets,^[17] due to lack of vascularity of the meniscus and the simplicity of the procedure. However, with improvements in arthroscopic techniques, devices, and methods, restoration is recommended for horizontal tears,^[18] and various techniques and treatment outcomes have been reported.^[19] These procedures have demerits, such as complicatedness, cartilage damage due to the knots or implants, and large surgical invasion. Against this background, we believed that a simple and minimally invasive surgical procedure with sufficient therapeutic effect was necessary. So we developed a new all-inside method utilizing the Fast-Fix (FF) 360 system (Smith & Nephew Endoscopy, Andover, MA), which is referred to as the “inter-leaf vertical suture technique”^[20] for repairing horizontal tears in the posteromedial part of the meniscus. We conjectured that by using this method to repair sports-related horizontal meniscal tears, it may be possible to apply adequate force to the cleaved site

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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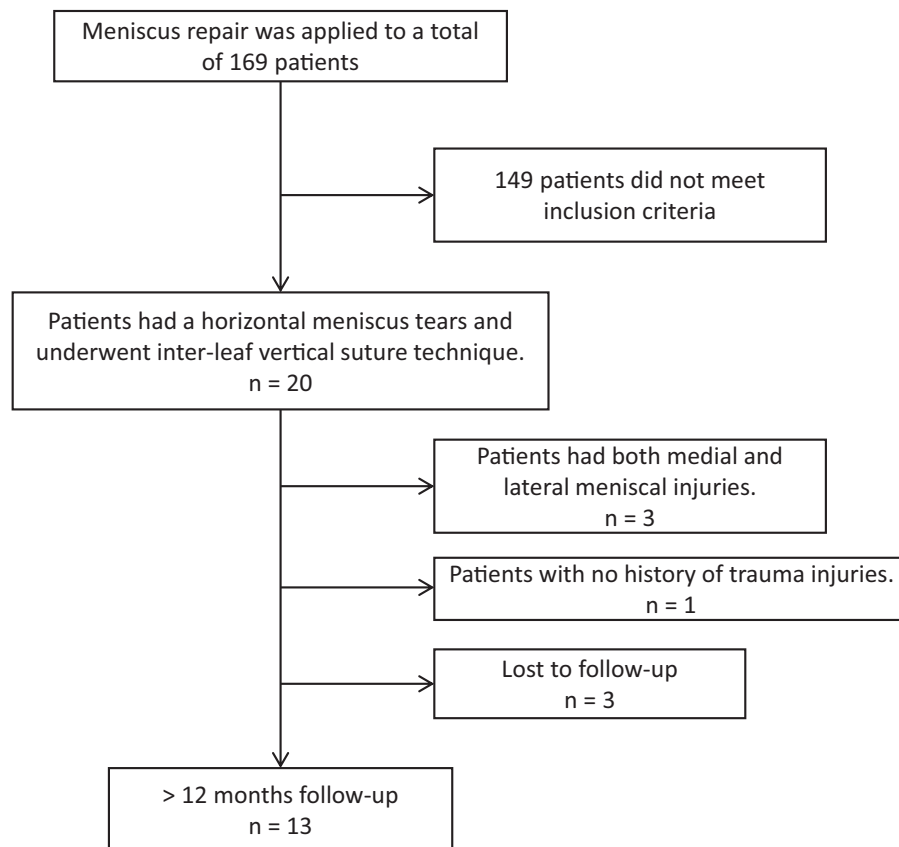


Figure 1. Study flow diagram.

to achieve superior meniscal restoration and clinical outcomes. If we were able to obtain good results from this surgery, this would indicate that our technique for horizontal meniscal tears would be able to promote meniscal repair by applying appropriate force to the injured area. The purpose of this study was to appraise, based on clinical and magnetic resonance imaging (MRI) findings, treatment outcomes of horizontal meniscal tears with the use of this new technique.

2. Methods

2.1. Patient selection

The subjects of this retrospective study were patients who underwent the inter-leaf vertical suture procedure^[20] for horizontal meniscal tears. Meniscus repair was performed in 169 patients at the Kyoto Kuramaguchi Medical Center in Japan between July 2015 and December 2017. Among them, 20 patients with horizontal meniscal tears underwent this procedure. All procedures were performed by 1 surgeon (KH) with more than 30 years of arthroscopy experience. The inclusion criteria were:

1. patients sustained sports-related horizontal tears in the posteromedial parts of the meniscus;
2. tears were grade 3 signal intensity on MRI;^[21] and
3. patients had continuous symptoms for ≥ 3 months despite conservative treatment or required early surgical intervention for a coexisting injury.

Exclusion criteria were tears in both the medial and lateral menisci ($n=3$) or degenerative horizontal tears with unclear history of trauma ($n=1$). Subjects who could not be followed for a minimum duration of 12 months were also excluded ($n=3$). Finally, 13 subjects were included in this study (Fig. 1).

The mean patient age at the time of surgery was 30 ± 14 years (males, 11 [85%]). The average height and body mass index of the patients were 173 ± 8 cm (range, 162–189 cm) and 22.5 ± 3.72 kg/m² (18.3 – 32.1 kg/m²), respectively. All patients reported participation in regular sports activities (soccer, 3; running, 2; rugby, 1; baseball, 1; dance, 1; sprint, 1; basketball, 1; judo, 1; kendo, 1; aikido, 1). The mean pre-injury Tegner activity score was 6.5 ± 1.5 . Follow-up lasted 20.4 ± 4.3 (range, 13–29) months. The medial meniscus was damaged in 11 cases and the lateral in 2 cases. Concurrent anterior cruciate ligament reconstruction (ACLR) with meniscal restoration was performed in 3 cases, and posterior cruciate ligament reconstruction (PCLR) was performed in 1 case.

This study was approved by the Kyoto Kuramaguchi Medical Center Review Board (20190130004). All patients gave written informed consent.

2.2. Surgical technique

All patients underwent arthroscopic meniscal repair with the following procedure, which we refer to as the inter-leaf vertical suture technique.^[20] The jagged free edges of the horizontal meniscal tear were debrided as sparingly as possible with a basket

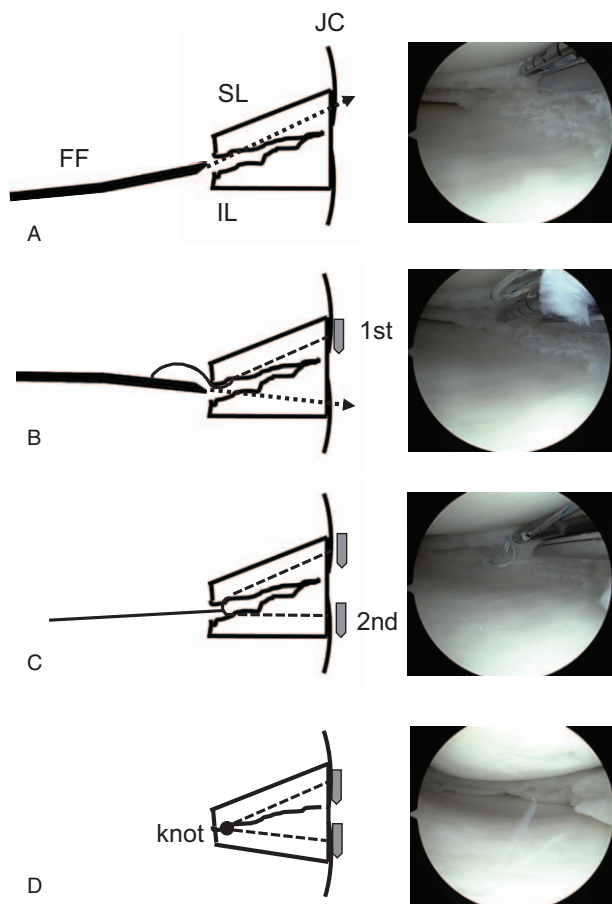


Figure 2. Inter-leaf vertical suture method schemata and arthroscopic images. (A) FF needle is inserted through the tibial surface of SL near its free edge, and the first anchor is placed outside the capsule (the dotted line shows the direction the anchor was inserted). (B) FF needle is inserted through the femoral surface of IL near its free edge, and the first anchor is placed outside the capsule (the dotted line shows the direction the anchor is inserted). (C) The anchors are tied with a sliding knot and the cleft is sutured vertically. (D) When tying and cutting a suture, the knot is embedded between SL and IL and the horizontal tear is closed. ●, knot; FF, Fast-Fix; SL, superior leaflet of horizontal torn meniscus; IL, inferior leaflet of horizontal torn meniscus; JC, joint capsule; 1st, 1st anchor of FF; 2nd, 2nd anchor of FF.

punch or shaver to clearly define the border between the superior and inferior leaflets of the tear. An FF with reversed curve needle was used. First, the FF needle was inserted from a point located on the tibial surface (i.e., lower surface) of the superior leaflet (SL), close to its free edge, and passed along the curve towards the femoral side. The first anchor was placed outside the joint capsule adjacent to the SL (Fig. 2A). Subsequently, the needle was inserted from the point located on the femoral surface (i.e., upper surface) of the inferior leaflet (IL), close to its free edge, and passed along the curve towards the tibial side. The second anchor was placed outside the joint capsule adjacent to the IL (Fig. 2B). After ligating the anchors with a sliding knot, the gap between the SL and IL was closed by placing vertical sutures (Fig. 2C). This enabled firm approximation between the SL and IL (Fig. 2D). The posteromedial part of the meniscus was approached from the anterior portal, and a maximum of 4 sutures were placed at 5- to 10-mm intervals.

Post-operatively, partial loading was allowed after 2 weeks and full loading was allowed after 5 weeks. A hinged rigid orthosis

was used to limit the extension to -30° and flexion to 90° until 2 weeks after surgery, and extension to 0° and flexion to 120° until 4 weeks after surgery. Loading in deep flexion positions such as squatting was prohibited until 2 months after surgery. Patients were allowed to return to competition after 4 months provided they had no meniscal symptoms and muscle strength had sufficiently recovered. Patients who underwent simultaneous reconstruction of the anterior or posterior cruciate ligament were allowed to return to competition after 6 months, based on the reconstruction protocol.

2.3. Clinical outcome study

Clinical outcomes were evaluated by Barrett criteria (joint line tenderness, effusion, and McMurray test)^[22] before surgery and at final follow-up, presence or absence of postoperative complications, timing of returning to sports, and Lysholm and Tegner activity scores at final follow-up.

2.4. Arthroscopic evaluation

Cartilage damage was evaluated arthroscopically based on the International Cartilage Repair Society (ICRS) grading system. We evaluated whether the knots were placed between SL and IL. The presence or absence of contact between each knot and articular cartilage was also evaluated.

2.5. MRI study

Both pre- and post-operative MRI images were available for evaluation in only 9 of the 13 patients. The follow-up MRI was performed after a mean duration of 7 ± 5 months (range, 2–21 months) following surgery. Meniscal injury was classified into grades 1 to 3 according to an established MRI grading system.^[21] Changes in signal intensity in the vicinity of the meniscocapsular attachment at the repaired part of the horizontally cleaved meniscus were evaluated qualitatively before and after surgery. Post-operatively, osteoarthritic changes such as thinning of cartilage, cartilage defects, and bone marrow edema were evaluated on MRI images.

2.6. Statistical Analysis

Wilcoxon signed-rank tests or McNemar tests were performed to evaluate the change in the Lysholm scores and MRI grades of the meniscal injury before and after surgery. All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan). $P < .05$ was defined as statistically significant.

3. Results

The clinical features of all patients are described in Table 1. In the Barrett criteria, joint-line tenderness and joint swelling were absent, and the McMurray test was negative, in all cases at final follow-up. The Lysholm score improved significantly from 70.2 ± 13.1 preoperatively to 98.9 ± 2.64 postoperatively ($P < .01$) (Fig. 3). There were no complications in any of the cases. At final follow-up, the Tegner activity score was 6.4 ± 1.5 . All patients were able to resume sports after 7.2 ± 3.1 months; the 9 cases of meniscal repair without simultaneous ACLR or PCLR resumed sports after 5.7 ± 2.6 months. Cartilage damage was graded as 0

Table 1
Symptoms, clinical outcomes, arthroscopic findings, and MRI findings.

Case	Age	Sex	Combined surgery	Barrett criteria			Lysholm score			Tegner activity score		Arthroscopic	MRI			
				Preoperatively		Final follow-up	Preoperatively		Final follow-up	Pre-injury	Final follow-up		ICRS grade	Postoperatively		
				Joint-line tenderness	Joint swelling	McMurray test	Joint-line tenderness	Joint swelling	McMurray test			Final follow-up		Grade	intensity near the joint capsule	
1	14	M	ACLR	+	+	+	-	-	-	45	100	7	7	0	1	low
2	21	M	ACLR	+	+	-	-	-	-	73	100	4	4	1		
3	17	M		+	-	+	-	-	-	85	91	9	9	0	2	low
4	23	M		+	-	+	-	-	-	80	100	7	7	0	3	low
5	21	M		+	-	-	-	-	-	72	100	7	7	0	1	low
6	42	M		+	+	+	-	-	-	51	100	6	6	0	3	high
7	59	M	PCLR	+	+	-	-	-	-	56	100	7	7	0	1	low
8	30	F		+	+	-	-	-	-	81	100	6	6	0	2	low
9	39	M		+	-	+	-	-	-	89	100	6	5	0	2	low
10	47	M	ACLR	+	+	+	-	-	-	75	100	4	4	0		
11	18	F		+	+	+	-	-	-	76	100	9	9	0		
12	41	M		+	+	+	-	-	-	57	95	7	6	0		
13	19	M		+	-	+	-	-	-	73	100	6	6	0	2	low

ACLR = anterior cruciate ligament reconstruction, F = female, ICRS = International Cartilage Repair Society; inter-leaflet, the knot was placed between superior leaflet and inferior leaflet, M = male, PCLR = posterior cruciate ligament reconstruction.

in 12 cases and 1 in 1 case (cartilage damage of the tibial joint surface in this case of lateral meniscal injury with anterior cruciate ligament injury) on arthroscopy according to the ICRS classification. In all cases, the meniscal suture knots were found buried between the meniscal SL and IL (i.e., inter-leaflet position) and were not in contact with the articular cartilage.

The MRI signal intensity of the meniscus was grade 3 in all cases pre-operatively; postoperatively, the intensity was grade 1 in 3 cases, grade 2 in 4 cases, and grade 3 in 2 cases ($P < .05$). Pre-operative MRI showed a high signal intensity horizontal line from the joint capsule to the articular surface in all cases; postoperative MRI identified only low signal intensity in the repaired part of the meniscus near the joint capsule in 8 cases (Fig. 4). Post-operative MRI did not identify any evidence of articular cartilage damage or bone marrow edema in any of the patients. Second-look arthroscopic surgery performed 14 months post-operatively in 1 of the patients, a 59-year-old man (Case 7) who underwent simultaneous posterior cruciate ligament reconstruction (PCLR), identified complete healing (Fig. 5).

4. Discussion

The inter-leaf vertical suture technique for sport-related horizontal meniscal tears appears to be a simple and effective

surgical method that promotes meniscal repair by applying appropriate force to the injured area.

The meniscus provides good congruency between the femoral condyle and the tibial plateau as well as auxiliary stabilization of the knee.^[3] Conventional surgical treatment for horizontal meniscal tears involved single-leaflet resection^[11] or resection of both leaflets^[17] primarily for reasons of convenience. However, it is now accepted that these procedures result in increased contact pressure between the femoral condyle and the tibial plateau and hence, an increased risk of osteoarthritis.^[7,8,23,24] Consequently, current surgical options attempt to preserve the meniscus. The inside-out method and the all-inside method, which were developed for repairing horizontal meniscal tears, have also been reported to have good treatment results.^[18–20,25–29] The main inside-out method involves a divergent double vertical suture.^[30] Several all-inside methods have been reported including the bio-absorbable implant method,^[25] methods using all-inside suture instruments (like Fast-Fix),^[20,26,29] and methods using devices with needles through which sutures pass (suture hook, knee scorpion etc.).^[31] Compared with the all-inside method, the inside-out method has a higher risk of neurovascular injury, requires more skin removal, and is likely to increase the operation time.^[25] Hence, all-inside methods, including the inter-leaf vertical suture procedure devised by us, are considered to be superior because they are less invasive and more convenient.

In several descriptions of the all-inside suture instrument method, the first anchor is inserted from the femoral surface of the SL and the second anchor from the tibial surface of the IL. The suture connecting the anchors straddles the free edges of SL and IL, and the meniscal cleft is closed using the overlock method.^[26,29] In this method, although each leaflet is drawn close to the edge and sutured in a wavelike manner, a gap may still occur between SL and IL.

In our modification of the all-inside method, we use the Fast-Fix to place the first anchor outside the joint capsule adjacent to the SL by approaching from the tibial surface of the SL, and we place the second anchor outside the joint capsule adjacent to the IL by approaching from the femoral surface of the IL. In the inter-leaf vertical suture technique developed by us, the torn surfaces of SL and IL are compressed together when sutured. Herein, we

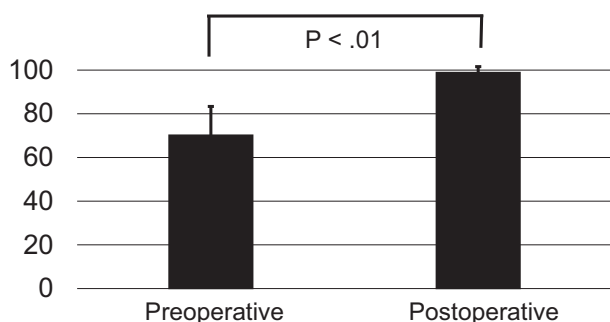


Figure 3. Pre- and post-operative Lysholm score. The post-operative Lysholm score is significantly higher than the pre-operative score ($P < .01$).

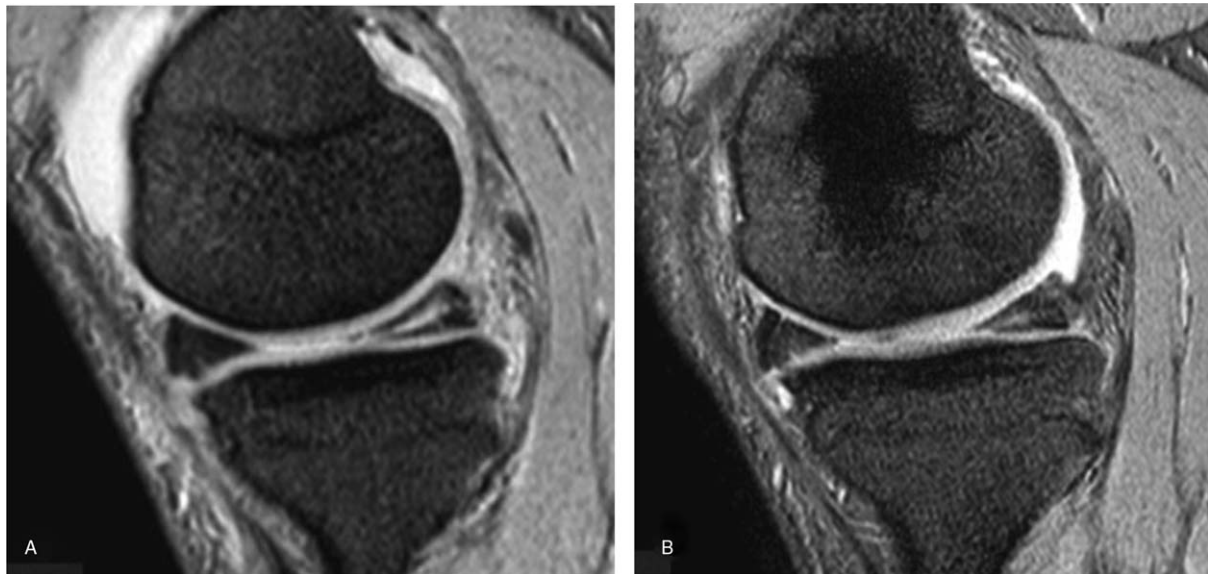


Figure 4. MRI images of representative case (Case7) (A) Before surgery: high signal intensity of a horizontal tear extending from the joint capsule to the articular surface. (B) After surgery: signal intensity is low near the free edge as well as near the joint capsule.

investigated the treatment outcomes of our technique.^[20] Our outcomes appear to be good for the following reasons: post-operative Barrett criteria were good; there were no serious complications; the Lysholm score significantly improved; and all patients were able to return to competitive sport.

Tiftikçi et al^[29] and Hoffelner et al^[32] described the changes from pre-operative high signal intensity to post-operative low intensity on MRI as an indicator of repair. Madhusudhan et al^[33] reported the utility of MRI as a supplemental tool to physical findings in determining meniscal healing. We evaluated horizontal meniscal tear healing on MRI and identified a significant improvement in grade, especially in terms of the change on MRI from preoperative high signal to postoperative low signal in the vicinity of the joint capsule at the meniscus in 8 of the 9 cases. In this procedure, it is possible to pass suture between the SL and IL to include tissue outside of the joint capsule. By ligating this suture, SL and IL can be approximated without leaving any gap.

More importantly, this ensures application of adequate pressure between the leaflets near the vascularized joint capsule to enable a good repair. In addition, it is possible that repair of the horizontal tear near the joint capsule reduces abnormal mobility of the meniscus near the joint capsule. This may further reduce the stimulation of local pain receptors^[4,34] and result in alleviation of clinical symptoms.

In the conventional all-inside method, since the suture is tied above the meniscus, the knot remains on its surface and remains in contact with the articular cartilage on the femoral side. This may contribute to a long-term risk of articular cartilage damage.^[35,36] In our method, as confirmed by arthroscopy, the knots were embedded between the SL and IL, avoiding contact with the femoral articular cartilage. In addition, there was no obvious cartilage damage identified on postoperative MRI.

In summary, the inter-leaf vertical suture procedure has several advantages:

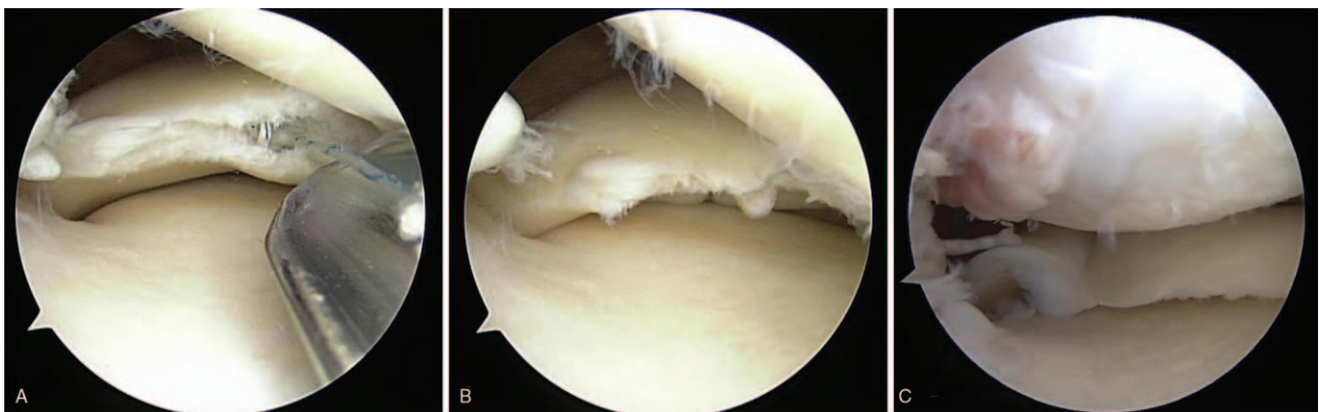


Figure 5. Arthroscopic images of meniscus in representative case (Case 7). (A) During meniscal repair at first surgery. (B) After meniscal repair at first surgery. (C) At the second look 14 months after surgery.

1. the tear is sutured vertically close to the free edge enabling better approximation without any gap between the SL and IL;
2. by running the suture from between the SL and IL to the outer side of the joint capsule, it is possible to apply force near the vascularized portion of the joint capsule; and
3. the use of vertical sutures between the SL and IL allows for the knots to be embedded between the leaflets, avoiding joint cartilage damage by the knots.

This study has several limitations. First, this is a retrospective study, with small case number and a short period of follow-up. Second, we did not compare our results with that of other meniscal repair procedures or partial meniscectomy. Third, inspection of meniscal repairs was done mainly by MRI rather than by arthroscopy. Fourth, the sex differences among the subjects were unequal.

5. Conclusion

The inter-leaf vertical suture technique for repair of sports-related horizontal meniscal tears enables application of adequate compression readily across the cleft to obtain excellent meniscal repairs and clinical outcomes. This technique preserves the meniscus and enables patients to resume sports.

Author contributions

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