Healing Status of Meniscal Ramp Lesion Affects Anterior Knee Stability After ACL Reconstruction

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Background: Although the biomechanical importance of the ramp lesion in the anterior cruciate ligament (ACL)–deficient knee has been demonstrated, there is no clear consensus on the appropriate treatment for ramp lesions during ACL reconstruction.

Purpose: To compare the postoperative outcomes for ramp lesions between patients treated with all-inside repair through the posteromedial portal and those whose ramp lesions were left in situ without repair during ACL reconstruction. We also determined whether ramp lesion healing status affected postoperative knee stability.

Study Design: Cohort study; Level of evidence, 3.

Methods: A total of 57 patients who underwent anatomic double-bundle ACL reconstruction between August 2011 and December 2017 had attendant ramp lesions. Of these, 25 ramp lesions that were considered stable were left in situ without repair (Nonrepaired group), and 25 ramp lesions, including 21 stable and 4 unstable lesions, were treated using all-inside repair through the posteromedial portal (Repaired group). We evaluated the side-to-side difference (SSD) in anterior tibial translation on stress radiographs and rotational stability by using the pivot-shift test 2 years after surgery, and healing status of the ramp lesions was evaluated on 3.0-T magnetic resonance imaging (MRI) scans 1 year after surgery.

Results: The mean SSDs in anterior translation were 2.4 ± 1.6 mm for the Nonrepaired group and 1.9 ± 1.6 mm for the Repaired group, with no significant differences. The positive ratios on the pivot-shift test were not significantly different between groups. Healing rates of ramp lesions on MRI scans showed a significant difference between the Nonrepaired group (60%) and the Repaired group (100%) ($P = .001$). The mean SSDs for knees in which the ramp lesion had healed as shown on MRI scans and those in which it had not healed were 1.9 ± 1.6 mm and 3.2 ± 1.1 mm, respectively, which was a significant difference ($P = .02$).

Conclusion: Healing rates of ramp lesions were significantly better in the Repaired group than in the Nonrepaired group, although postoperative knee stability was not significantly different between groups. Anterior laxity in the knees in which the ramp lesion was unhealed was significantly greater compared with the knees in which the ramp lesion healed. All-inside repair through the posteromedial portal was a reliable surgical procedure to heal ramp lesions.

Keywords: anterior cruciate ligament; ramp lesion; repair; anterior stability

Concomitant intra-articular lesions are commonly seen in anterior cruciate ligament (ACL)–injured knees, and medial meniscal tears occur in approximately 47% to 61% of ACL-injured knees.[1,15] Peripheral longitudinal tears of the medial meniscus posterior horn (MMPH) around the meniscocapsular junction are frequently associated with ACL injuries, termed *ramp lesions* by Strobel.[22] The incidence of ramp lesions in ACL-deficient knees has been reported to be between 9.3% and 30.9%.[3,4,8,13,20]

The biomechanical importance of the ramp lesion was recently demonstrated.[6,17,21] Stephen et al[21] demonstrated in cadaveric knees that anterior and external rotational laxities were significantly increased after sectioning of the posteromedial meniscocapsular junction in ACL-deficient knees. Those investigators also showed that these knees were not restored after ACL reconstruction alone but were restored by ACL reconstruction combined with posteromedial meniscocapsular repair. Therefore, ramp lesions should be appropriately treated at the time of ACL reconstruction to avoid causing increased forces in the ACL graft. However, no clear consensus is available on the appropriate treatment for ramp lesions.[2,3,12,14,21,23] Thaunat et al[23] reported that all-inside suture repair of medial meniscal ramp lesions using a suture hook through a posteromedial

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portal provided a high rate of meniscal healing. In contrast, Liu et al[14] found no significant difference regarding the healing status of stable ramp lesions between patients treated with surgical repair or abrasion and trephination alone during ACL reconstruction.

The purpose of this study was to compare the postoperative outcomes for meniscal ramp lesions between patients treated with suture repair and those whose lesions were left in situ without repair during ACL reconstruction. We also determined whether the healing status of ramp lesions affected postoperative knee stability. We hypothesized that all-inside suture repair through the posteromedial portal would be more effective to heal ramp lesions than leaving lesions in situ without repair. And, most important, we hypothesized that postoperative knee stability would be inferior in knees with unhealed ramp lesions compared with knees that had healed ramp lesions.

METHODS

Between August 2011 and December 2017, patients who underwent primary anatomic double-bundle ACL reconstruction by use of the semitendinosus tendon at our institute were included in our study. Patients were excluded from our study if they had single-bundle reconstruction, revision ACL reconstruction, bilateral ACL injuries, or multiple ligamentous injuries. Patients who had a grade 1 or 2 medial collateral ligament injury were not excluded. A total of 259 patients met our criteria. Of these, 34 patients who were lost to follow-up within 2 years after surgery were excluded. A further 8 patients who reinjured their reconstructed ACL within 2 years after surgery were also excluded. The remaining 217 patients were included in our study. This study was approved by our institutional review board.

Of the 217 patients, 104 patients who had no medial meniscal tear served as a control group (No Tear group). The remaining 113 patients had concomitant medial meniscal tears of the posterior horn; of these, 57 patients had ramp lesions (50.4%). Of the 113 patients with concomitant medial meniscal tears, 56 patients had medial meniscal body tears located in the white-white zone or red-white zone. Of these, 24 patients underwent medial meniscal repair via an inside-out (IO) technique for longitudinal tears located in the red-white zone (IO group), and 32 patients who had avascular zone tears or complex tears underwent partial meniscectomy or partial meniscectomy before ACL reconstruction (Resected group) (Figure 1).

Surgical Technique

All ACL reconstructions were performed by surgeons (K.H., M.T.) who had >10 years of experience performing ACL reconstructions. All patients underwent anatomic double-bundle ACL reconstruction with a semitendinosus tendon autograft as previously described.[9] In line with a previous report, we performed systematic arthroscopic exploration of the MMPH to identify the ramp lesion.[20] The transcondylar view, in which a 30° arthroscope is introduced from the anterolateral portal through the intercondylar notch between the posterior cruciate ligament and the medial wall of the intercondylar notch into the posterior recess, allowed especially good visualization of the posteromedial compartment, including the meniscocapsular junction of the MMPH, and the presence of a ramp lesion was verified (Figure 2A). Ramp lesions were defined as full-thickness longitudinal tearing of the MMPH peripheral attachment at the meniscocapsular junction and in the red zone with a remaining meniscal wall, whereas other meniscal lesions were defined as body tears.

Between August 2011 and March 2015, ramp lesions that were considered stable by probing of the MMPH were left in situ without suture repair in 25 patients (Nonrepaired group). In 7 patients whose ramp lesions were considered unstable, the lesions were repaired by use of the Fast-Fix Meniscal Repair System (Smith & Nephew) through the standard anterior portal. However, because of the small number of patients, this group was excluded from this study. Tears that could be displaced into the intercondylar notch with the probe were considered unstable tears.

Between April 2015 and December 2017, regardless of instability, all ramp lesions were repaired by all-inside suturing through the posteromedial portal in 25 patients (Repaired group). In this group, 21 ramp lesions were stable and 4 were unstable. After the bone tunnels were created for ACL reconstruction, ramp lesions were repaired. The knee was placed at 90° of knee flexion with a foot support on the operative table, and 2 posteromedial portals (standard and high portal) were created. We did not perform any abrasion of the tear surface. An Accu-Pass suture shuttle that was curved to the left by 45° (Smith & Nephew) was used for left knees, and a right-curved shuttle was used for right knees. An Accu-Pass suture shuttle loaded with No. 2 nylon was introduced through the standard posteromedial portal, and the tip of the hook penetrated the central fragment of medial meniscal tissue from superior to inferior (Figure 2B). The loop of the nylon was guided and brought out to the high posteromedial portal. Then, the nylon was switched to an Ultrabraid No. 2 suture (Smith & Nephew).

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Ethical approval for this study was obtained from the Gunma Chuo Hospital Ethical Review Committee (approval No. 2017-040).

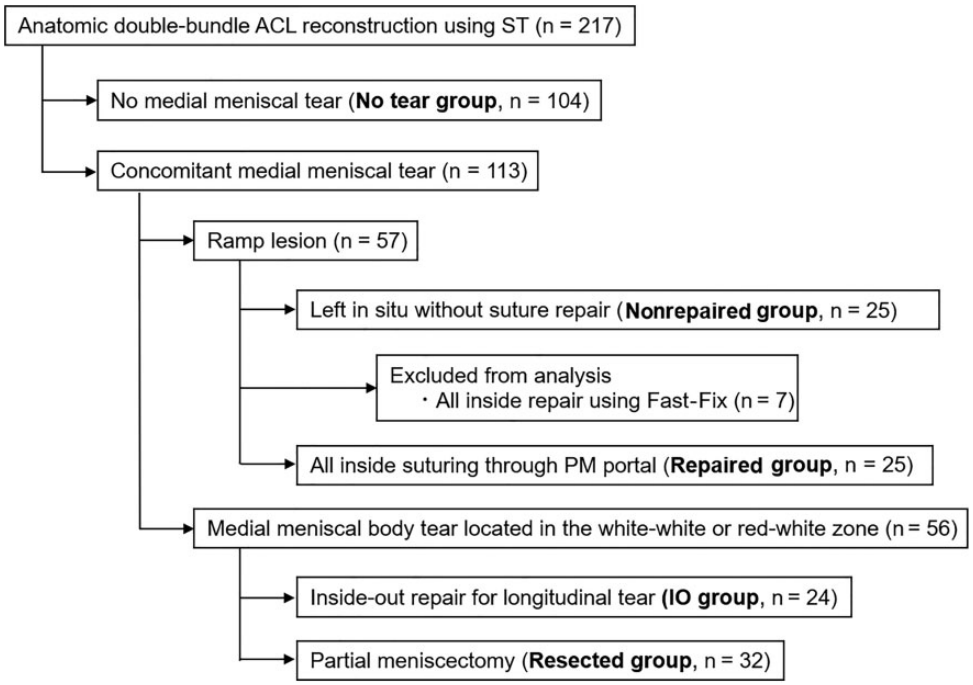

Figure 1. Flowchart. ACL, anterior cruciate ligament; IO, inside-out; PM, posteromedial; ST, semitendinosus.

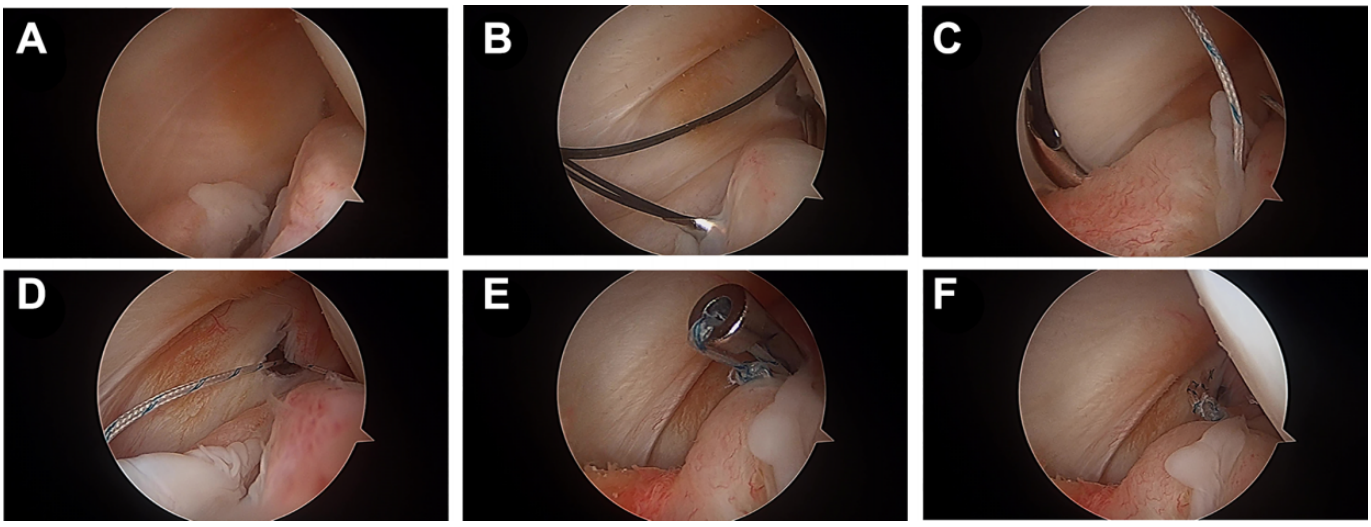

Figure 2. All-inside suture repair through the posteromedial portal for a ramp lesion in the right knee. (A) Identification of a ramp lesion by transcondylar view. (B) The tip of the hook penetrated the central fragment of the medial meniscal tissue from superior to inferior, and the loop of the nylon was guided. (C) The tip of the hook penetrated the meniscal peripheral rim tissue and meniscocapsular structure from inferior to superior, and the free end of the nylon was guided. (D) After switching to the Ultrabraid No. 2 suture, the surgeon brought it out via the standard posteromedial portal. (E, F) A sliding knot suture was applied to the posterior part of the meniscus by use of a knot pusher and then cut.

Next, the Accu-Pass suture shuttle was introduced through the standard posteromedial portal again, and the tip of the hook penetrated the meniscal peripheral rim tissue and meniscocapsular structure from inferior to superior (Figure 2C). The free end of the nylon was guided and brought out to the high posteromedial portal. After switching to the Ultrabraid No. 2 suture, the surgeon brought it out through the standard posteromedial portal (Figure 2D). A sliding knot suture was applied to the posterior part of the meniscus (Figure 2, E and F). This maneuver was repeated 1 or 2 times depending on the length of the tear. The average number of sutures was 1.5.

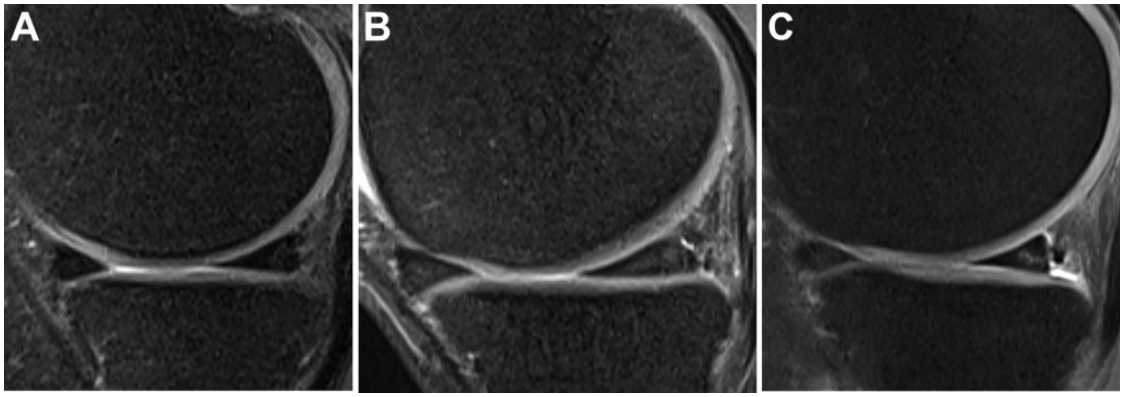

Figure 3. Magnetic resonance imaging evaluation of the healing status of the ramp lesions 1 year after anterior cruciate ligament reconstruction. (A) Completely healed ramp lesion with grade 0 signal. (B) Partially healed ramp lesion with grade 2 linear signal. (C) Unhealed ramp lesion with grade 3 linear signal.

Postoperative Rehabilitation

The postoperative rehabilitation protocol was the same for all patients. The knee was immobilized at 20° of flexion with a knee brace for 1 week. Range of motion exercises were initiated without limit at 1 week after surgery. Partial weightbearing was started 1 week after surgery, progressing to full weightbearing with an ACL brace at 3 weeks. All patients were discharged from the hospital between 2 and 3 weeks after surgery. Jogging was started at 4 months. We allowed jumping and cutting exercises at 6 months and full-contact sports participation at 8 months.

Postoperative Outcomes

At 2 years after surgery, we measured the side-to-side difference (SSD) in anterior tibial translation on stress radiographs using a Telos stress device (type SE 2000; Telos) at 20° of knee flexion under an anterior drawer force of 150 N and evaluated anterior knee laxity. Rotational stability was assessed by the manual pivot-shift test 2 years after surgery. We evaluated pivot-shift test findings according to the method described by Yasuda et al[24] and categorized them as negative, +, and ++. Clinical results were determined by the Lysholm score 2 years after surgery.

At 1 year after surgery, 3.0-T magnetic resonance imaging (MRI) (Siemens) was performed on all knees. The healing status of the ramp lesions was evaluated with the following MRI parameters: sagittal turbo, spin-echo, fat-saturated proton density, repetition time/echo time (3500/8.6 ms), and 2-mm slice thickness. The MRI scans were evaluated by 2 orthopaedists (K.H., M.T.) to reach a consensus. They could not be blinded because the suture was visible on the MRI scans. The signal grade at the ramp lesion was assessed through use of the criteria of Crues et al[5]: grade 0, low signal intensity; grade 1, irregularly marginated intrameniscal signal; grade 2, linear signal without communication with an articular surface; and grade 3, similarly linear signal intensity extending to the articular surface (Figure 3). A signal of grade 0 to 1 indicated a completely healed meniscus. Grade 2 indicated a partially healed meniscus, and grade 3 indicated an unhealed meniscus. The ramp lesion was considered healed if it was judged completely healed or partially healed.

Data Analysis

The Student *t* test was used to compare the SSD in anterior translation, age, and time between injury and surgery between the groups. The Mann-Whitney *U* test was used to compare pivot-shift test results and Lysholm scores between the groups, and the chi-square test was used to compare sex distribution and the healing status of the ramp lesions between the groups. *P* values $<.05$ were considered significant. All statistical analyses were performed using SPSS software (SPSS Inc).

RESULTS

The positive ratios on the pivot-shift test in the No Tear group, IO group, and Resected group were 12.5% (13/104 knees), 16.7% (4/24 knees) and 15.6% (5/32 knees), respectively, and these were not significantly different among the groups; the values in the Nonrepaired group and Repaired group were 16.0% (4/25 knees) and 16.0% (4/25 knees), respectively, which were not significantly different between the groups (Table 1). Postoperative Lysholm scores were not significantly different among the groups (Table 1).

The postoperative mean ± SD values for SSDs in anterior translation were 2.0 ± 2.1 mm for the No Tear group, 2.2 ± 2.4 mm for the IO group, and 2.7 ± 2.7 mm for the Resected group, with no significant difference among the groups. The postoperative SSDs in patients who had ramp lesions were 2.4 ± 1.6 mm for the Nonrepaired group and 1.9 ± 1.6 mm for the Repaired group, with no significant difference between the groups (Table 1). Age, sex, time from injury to surgery, and preoperative mean SSDs in anterior translation were not significantly different between the Nonrepaired and Repaired groups.

TABLE 1
Patient Characteristics and Postoperative Outcomes[a]

	No Tear Group (n = 104)	IO Group (n = 24)	Resected Group (n = 32)	Nonrepaired Group (n = 25)	Repaired Group (n = 25)
Age, y, mean	26.9	26.0	31.8	29.5	26.6
Sex, male/female, n	59/45	10/14	15/17	13/12	17/8
Time from injury					
Mean, days	317	208	1257	680	494
>6 months, n (%)	15 (14.4)	6 (25)	18 (56.3)	5 (20)	9 (36)
Tegner activity scale score, mean	6.8	6.5	5.6	6.0	6.8
SSD of anterior tibial translation, mm, mean ± SD					
Preoperative	7.6 ± 3.5	7.0 ± 2.8	7.4 ± 4.5	8.1 ± 4.0	8.1 ± 3.2
2 y after surgery	2.0 ± 2.1	2.2 ± 2.4	2.7 ± 2.7	2.4 ± 1.6	1.9 ± 1.6
Pivot-shift test result, n					
Negative	91	20	27	21	21
+	8	2	3	4	3
++	5	2	2	0	1
Lysholm score, mean	98.4	95.1	97.4	98.5	98.7
Postoperative MRI results, n					
Complete healing				10	20
Incomplete healing				5	5
Nonhealing				10	0

[a]IO, inside-out technique; MRI, magnetic resonance imaging; SSD, side-to-side difference.

On postoperative MRI scans, 10 ramp lesions (40%) in the Nonrepaired group were completely healed, 5 (20%) were partially healed, and 10 (40%) were unhealed. In the Repaired group, 20 (80%) knees were completely healed, 5 (20%) were partially healed, and no knees were unhealed. The healing rate of ramp lesions showed a significant difference between the Nonrepaired group (60%) and Repaired group (100%) ($P = .001$).

The SSDs for 40 knees in which ramp lesions healed and 10 knees in which ramp lesions were unhealed on MRI scans were 1.9 ± 1.6 mm and 3.2 ± 1.1 mm, respectively, which was a significant difference ($P = .02$).

We found that 2 knees in the Nonrepaired group required medial meniscectomy for a subsequent bucket-handle tear in the white-white zone 1 year or 5 years after ACL reconstruction. In the Repaired group, no knee required subsequent meniscal surgery. A further 3 knees in the IO group required medial meniscectomy for a retear at the repaired site within 2 years after ACL reconstruction.

DISCUSSION

Our study demonstrated that postoperative anterior stability was significantly inferior in knees in which ramp lesions were unhealed compared with knees in which ramp lesions healed. The healing rate of ramp lesions after all-inside suturing through the posteromedial portal was significantly superior to that of ramp lesions left in situ without suture repair for stable ramp lesions.

A ramp lesion constitutes a stable longitudinal meniscal tear pattern located in a highly vascular zone. Previous studies have reported reasonable clinical outcomes with similar tear patterns left in situ without suture repair at the time of ACL reconstruction.[7,14,18] Shelbourne and Rask[18] reported that 10.8% of patients with stable peripheral vertical medial meniscal tears >1 cm that were left in situ without repair and 6.0% of patients treated using abrasion and trephination required subsequent surgeries for medial meniscal symptoms at a mean of 3.7 years after ACL reconstruction. Those investigators concluded that such tears could be treated successfully without suture repair. Liu et al[14] reported that 31 of 33 stable ramp lesions (94%) <1.5 cm treated using abrasion and trephination alone had healed on follow-up MRI scans after ACL reconstruction. In our study, only 2 of 25 stable ramp lesions (8%) left in situ without repair required medial meniscectomy after ACL reconstruction for subsequent bucket-handle tears. However, 10 of 25 stable ramp lesions (40%) were judged to be unhealed on postoperative MRI scans. Because we did not perform abrasion or trephination in these knees, this may have caused the low healing rate for ramp lesions.

The MMPH has been recognized as a secondary restraint to anterior tibial translation in the ACL-deficient knee.[11,19] Recent biomechanical studies have demonstrated that anterior tibial translation and external rotational laxities were significantly increased after sectioning of the posteromedial meniscocapsular junction in ACL-deficient knees.[21] These studies also have shown that anterior and external rotational instability were not restored after ACL reconstruction alone. Our study showed that postoperative anterior stability was significantly inferior in knees in which ramp lesions were unhealed compared with knees in which ramp lesions had healed. In contrast, we found no significant difference in postoperative stability between knees that had no medial meniscal tears and knees that underwent medial meniscectomy for avascular zone tears. Our results indicated that the ramp lesion was a particular type of meniscal injury that affected knee stability after

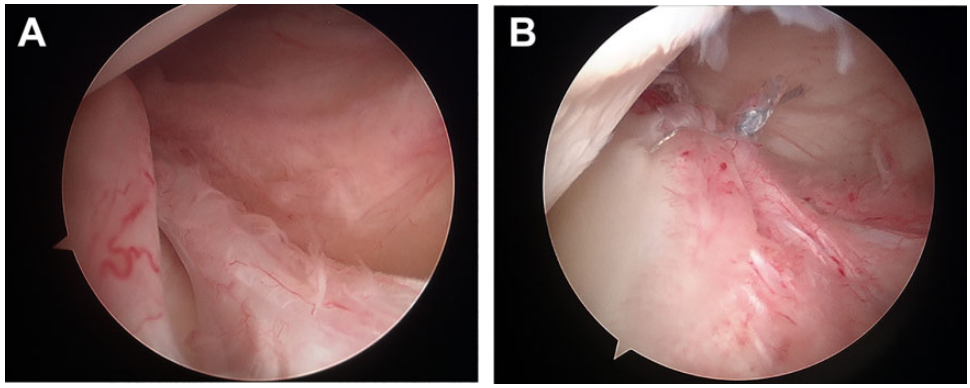

Figure 4. Arthroscopic images from a transcondylar view of the left knee. (A) The detached peripheral meniscocapsular structure sagged distally on knee flexion. (B) The meniscocapsular structure was lifted by all-inside suturing placed perpendicular to the tear, and the lesion was anatomically repaired.

ACL reconstruction and suggested that ramp lesions need to be appropriately treated at the time of ACL reconstruction to achieve long-term knee stability.

At arthroscopy, ramp lesions are easily missed when the knee is viewed through anterior visualization because most ramp lesions are not unstable during probing. Therefore, many authors have advocated that a transcondylar view using a 70° arthroscope through the intercondylar notch should be used to better visualize ramp lesions.[4,8,16,20] When observing from a transcondylar view during surgery, we can often see hypermobility of the detached meniscocapsular structure in the ramp lesion, and the posterior meniscocapsular structure sags posteriorly and distally during knee flexion.[2,4] Furthermore, contraction of the semimembranosus at its insertion along the posteromedial capsule may stress the peripheral part of the lesion, resulting in an increase in the meniscocapsular separation.[10] These factors could make it difficult for ramp lesions to heal spontaneously. Even if a ramp lesion is considered stable by probing from an anterior portal, it may be necessary to restrict passive knee flexion to <90° and avoid active flexion for a few weeks after ACL reconstruction so as not to displace the meniscocapsular structure when it is treated without suture repair. In our series, the postoperative rehabilitation protocol was the same for all patients, and no limits on knee motion were imposed from 1 week after ACL reconstruction. This may have caused the low healing rate in the Nonrepaired group. Future studies are necessary to investigate whether sagging of the peripheral part of the ramp lesion posteriorly and distally during knee flexion affects lesion healing without suture repair.

Several authors have reported a high healing rate for ramp lesions after suture repair using a suture hook through the posteromedial portal.[2,3,23] Ahn et al[2] conducted second-look arthroscopy to evaluate 39 patients after all-inside suture, concurrent ACL reconstruction via a suture hook through the posteromedial portal for MMPH tears; the investigators reported that all knees showed complete healing of posterior horn tears. Because we did not perform second-look arthroscopy for all knees, we assessed the healing status by MRI. All ramp lesions healed after all-inside repair using an Accu-Pass suture shuttle through the posteromedial portal. During this procedure, a transcondylar view allows sufficient visualization of the posteromedial corner of the knee. It also allows placement of vertically oriented sutures, which have strong pullout strength.[2] Furthermore, this suture technique can lift the peripheral meniscocapsular structure that has sagged distally, especially in chronic cases, by placing the sutures perpendicular to the tear without entrapment of the posterior capsule, resulting in anatomic repair (Figure 4).

A repair technique with Fast-Fix for ramp lesions has also been reported.[12,21] Stephen et al[21] repaired posteromedial meniscocapsular lesions using Fast-Fix in cadaveric knees and reported that some of the Fast-Fix anchors did not engage the capsule. Sonnery-Cottet et al[20] also suggested that Fast-Fix sutures could not adequately repair meniscocapsular lesions. This procedure requires careful attention to deployment of the Fast-Fix anchor. Especially in chronic situations, repair by Fast-Fix may lead to difficulty in achieving anatomic reduction of the meniscocapsular structure that has sagged distally.[17] In such knees, all-inside suturing through the posteromedial portal is more effective, as mentioned above. Inside-out sutures would also adequately repair ramp lesions but require a posteromedial incision.

Our study has some limitations. First, we had a small sample size in each group and short duration of follow-up. Second, treatment options for ramp lesions were not randomly and prospectively allocated. Therefore, our study had a selection bias. Further, we did not perform abrasion or trephination of ramp lesions that were not repaired. Third, the assessment of rotational stability was not quantitative. Fourth, investigator blinding was not used. MRI evaluation could not be blinded because sutures were visible on MRI scans. Fifth, we did not perform second-look arthroscopy to determine the actual healing of ramp lesions unless patients reported symptoms. Because it is unclear whether MRI findings correctly reflect the healing status of the ramp lesions, MRI evaluation has a significant risk of false-negative results. Sixth, the influence of lateral meniscal lesions was not considered.

CONCLUSION

Healing rates of ramp lesions in the Repaired group were significantly better than that in the Nonrepaired group, although postoperative knee stability was not significantly different between the groups. Anterior stability was significantly inferior in the knees in which the ramp lesion was unhealed compared with knees in which the ramp lesion healed. All-inside repair through the posteromedial portal was a more reliable surgical procedure to heal ramp lesions.

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