Outcomes More Than 2 Years After Meniscal Repair for Radial/Flap Tears of the Posterior Lateral Meniscus Combined With Anterior Cruciate Ligament Reconstruction

Akira Tsujii,* MD, PhD, Yasukazu Yonetani,* MD, PhD, Kazutaka Kinugasa,† MD, PhD, Tomohiko Matsuo,‡ MD, PhD, Kenji Yoneda,‡ MD, PhD, Tomoki Ohori,§ MD, PhD, and Masayuki Hamada,*|| MD, PhD
Investigation performed at Hoshigaoka Medical Center, Hirakata, Japan

Background: Meniscal function after repair of radial/flap tears of the posterior horn of the lateral meniscus (LM) with anterior cruciate ligament reconstruction (ACLR) has not been comprehensively investigated.

Purpose: To evaluate not only the clinical and radiographic outcomes of patients with repair of radial/flap tears of the posterior LM with ACLR but also the healing status of the repaired meniscus and changes of chondral status with second-look arthroscopy.

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

Methods: From January 2008 to April 2016, 41 patients of a consecutive series of 505 primary anatomic ACLR cases had a concomitant radial/flap tear of the posterior horn of the LM and underwent side-to-side repair with an inside-out or all-inside technique. All patients were followed for >2 years, evaluated clinically and radiologically (radiograph and magnetic resonance imaging [MRI]), and compared with a control group without any concomitant injuries that underwent ACLR. Of the 41 patients, 30 were assessed by second-look arthroscopy 2 years postoperatively.

Results: The mean follow-up times of the study and control groups were 3.4 and 3.9 years, respectively. The study group showed no significant differences in clinical findings, lateral joint space narrowing on radiograph, and coronal extrusion on MRI as compared with the control group, whereas sagittal extrusion on MRI progressed significantly in the study group (1.2 ± 1.5 mm vs 0.32 ± 1.0 mm, $P < .001$). Eighteen patients (60%) obtained complete healing; 9 (30%) showed partial healing; and 3 (10%) failed to heal on second-look arthroscopy. Changes of chondral status in the femoral condyle showed no significant difference between the groups ($P = .29$). However, chondral status of the lateral tibial plateau worsened significantly in the study group ($P = .0011$).

Conclusion: The clinical and radiographic outcomes after repair of radial/flap tears of the posterior horn of the LM as combined with anatomic ACLR were successful and comparable with those after isolated ACLR without any other injuries at a mean postoperative follow-up of 3.4 years, except for sagittal extrusion on MRI. Chondral lesions of the lateral tibial plateau deteriorated regardless of meniscal healing at 2 years postoperatively. Surgeons should keep in mind that chondral injuries might progress over the midterm.

Keywords: lateral meniscus; posterior horn tear; meniscal repair; meniscal function; ACL reconstruction; second-look arthroscopy

Posterior horn tears of the lateral meniscus (LM) are occasionally accompanied with an anterior cruciate ligament (ACL) tear, with a reported incidence of 7% to 12%.[3] The meniscus has functions of load transmission, shock absorption, lubrication, and joint stability.[5] If the meniscus is torn, it loses these functions, and detrimental changes can occur.[15,23] Biomechanical studies have shown that LM posterior horn tears can increase tibiofemoral contact pressure, because the tears result in the loss of meniscal circumferential hoop stress, and that repair can normalize the contact pressure down to almost normal values.[7,16] Furthermore, repair could restore knee stability.[21] Thus, meniscal repair should be considered for such tears. However, there are few clinical reports about repairing posterior horn tears of the LM as combined with ACL reconstruction (ACLR), and whether meniscal function can be preserved has not been well investigated.

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Meniscal function is commonly assessed by clinical symptoms, radiograph examination, and magnetic resonance imaging (MRI). In recent years, meniscal extrusion on MRI has been reported to be an important evaluation method for remaining meniscal function, especially in root/horn tears.[9] More detailed assessment of meniscal tears, such as tear patterns, tear lengths, and stability, can be evaluated only by arthroscopy. In addition, since a repaired meniscus cannot be fully evaluated by MRI,[14,24] arthroscopic assessment has become the gold standard for evaluating the healing status of the meniscus.[11] Therefore, meniscal function should be comprehensively evaluated with all these procedures.

The purpose of this study was to compare the clinical and radiographic outcomes of (1) patients with repaired radial/flap tears of the posterior horn of the LM combined with ACLR and (2) patients with isolated ACLR without any other injuries. In addition, the healing status of the repaired meniscus and changes of chondral status were evaluated with second-look arthroscopy.

It was hypothesized that repairing the radial/flap tears of the posterior horn of the LM would result in similar clinical and radiological outcomes as compared with isolated ACLR and would restore meniscal function.

METHODS

Between January 2008 and April 2016, a total of 505 patients underwent primary anatomic ACLR with autogenous bone–patellar tendon–bone (BTB) grafts or hamstring tendon (HS) grafts, and 53 patients had radial/flap tears of the posterior LM that were repaired at our hospital. Data from the patients' medical records were retrospectively reviewed with the informed consent of all subjects. Of these, 41 knees of 41 patients who were followed up for >2 years postoperatively were included in this study. Patients with longitudinal or complex tears of the LM and medial meniscal tears were excluded. Posterior root tears of the LM were also excluded when repaired by the transosseous pullout technique. A control group of patients who underwent ACLR without any concomitant injuries was then identified (98 knees of 96 patients). All study protocols were approved by the local ethics committee (HG-IRB 1646).

Second-look surgery with hardware removal was performed in 30 patients in the study group and 66 patients in the control group at postoperative 2.3 and 2.9 years, respectively. Follow-up radiograph and MRI were examined in all patients at final follow-up.

Surgical Technique and Postoperative Rehabilitation

First, arthroscopic examination was performed, and the LM was assessed by probing. If a radial/flap tear of the posterior horn of the LM was detected (Figure 1A), meniscal repair was then performed. According to previous reports, pullout repair was not effective when the site of the tear was >6 mm from the root attachment,[7] and side-to-side repair can be performed in radial tears with a root remnant of adequate tissue quality.[3] Thus, meniscal repair was performed by side-to-side repair with an inside-out technique (with the Henning instrument; Stryker) or an all-inside technique (with a suture hook) with No. 2-0 braided polyester suture (Stryker). The torn edge of the meniscus and adjacent synovium were refreshed with a meniscal rasp to promote healing with an adequate vascular supply. In cases of inside-out suture, after a skin incision was made at the lateral aspect of the knee, the retractor was placed between the iliotibial tract and the biceps tendon in front of the gastrocnemius muscle to protect the common peroneal nerve; then, a horizontal suture (Figure 1B) or tie-grip suture technique was performed against the joint capsule (transcapsular suturing).[12,22] In case of all-inside suture, a vertical suture was placed at the tear site with a suture hook, and No. 2-0 polyester thread was withdrawn through the anterolateral portal. Another No. 2-0 polyester thread was passed through at the other tear site in the same manner. Then, the shuttle relay carried a No. 2-0 braided polyester suture, and both ends of the suture were tied with a sliding knot to complete the horizontal suture. After the meniscus was repaired, all patients underwent anatomic ACLR with BTB (rectangular) or HS (triple bundle) grafts with the same previously reported surgical technique.[19]

The postoperative weightbearing schedule differed in the early phase between the groups. In the study group, after nonweightbearing for 3 or 4 weeks, partial weightbearing was started, followed by full weightbearing after 2 further weeks. In the control group, partial weightbearing was allowed at 2 weeks, followed by full weightbearing at 4 weeks. The immobilization period was the same in the 2 groups. After brace immobilization for 1 week, range of motion exercise was started in both groups. Jogging was allowed at 3 months, while return to strenuous sports activities was permitted at 8 to 9 months.

Clinical Assessments

Clinical outcomes were assessed by pain, range of motion, swelling, the Lachman test, and the side-to-side difference of anteroposterior stability at final follow-up. Anteroposterior

‖Address correspondence to Masayuki Hamada, MD, PhD, Department of Sports Orthopaedics, Hoshigaoka Medical Center, 4-8-1, Hoshigaoka, Hirakata, Osaka 573-8511, Japan (email: hamada-m@umin.ac.jp).
*Department of Sports Orthopaedics, Hoshigaoka Medical Center, Hirakata, Japan.
†Department of Sports Orthopaedics, Osaka Rosai Hospital, Sakai, Japan.
‡Department of Sports Orthopaedics, Moriguchi Keijinkai Hospital, Moriguchi, Japan.
§Department of Orthopaedic Surgery, Graduate School of Medicine, Osaka University, Suita, Japan.
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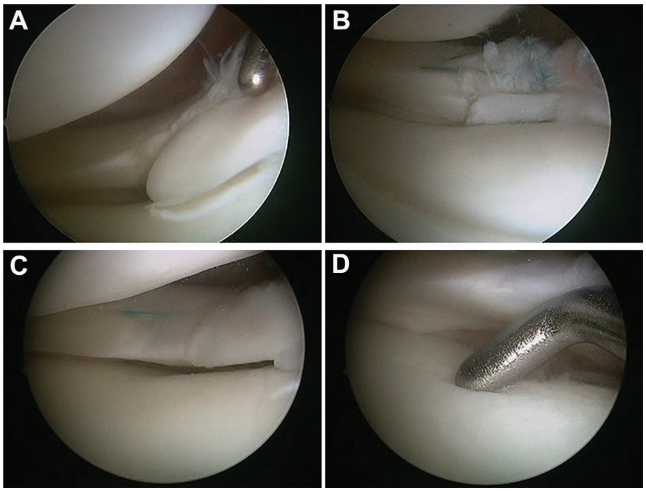

Figure 1. Arthroscopic images of a 16-year-old female patient. (A) Flap tear of the posterior horn of the lateral meniscus. (B) Inside-out repair was performed, and no chondral lesion was detected. (C) Complete healing was obtained, and (D) a chondral fissure was observed at the lateral tibial plateau at second-look arthroscopy at 2 years postoperatively.

stability was evaluated by the KT-1000 arthrometer (MEDmetric Corp).

Radiographic Evaluation: Radiograph and MRI

The Rosenberg view (45° of posteroanterior flexion weight-bearing radiographs) was used to evaluate lateral joint space width (Figure 2, A and D). Lateral joint space width was measured from the center of the lateral femoral condyle to the center of the lateral tibial plateau with the digital radiology viewing program SYNAPSE (FUJIFILM). The difference between the pre- and postoperative (final follow-up) lateral joint spaces was calculated and compared between the groups.

A 1.5-T MRI scanner (TOSHIBA) was used in all patients. Coronal and sagittal proton density images were obtained (repetition time, 2400 ms; echo time, 18 ms). A 16-cm field of view with a 192 × 192 matrix was used. Slices were 4 mm in thickness, with a gap of 0.8 mm. Meniscal extrusion was measured in the coronal and sagittal planes according to a previous report.[1] Coronal extrusion was measured by the distance from the peripheral margin of the lateral tibial plateau to the meniscocapsular junction in the midcoronal plane (Figure 2, B and E). Sagittal extrusion was measured by the distance from the inner margin of the anterior LM to the meniscocapsular junction of the posterior LM in the midsagittal plane (Figure 2, C and F). Then, differences between preoperative and final follow-up results were calculated.

The reliability calculations were based on each parameter measured by the same observer (repeated 3 times) and by 2 observers (A.T., Y.Y.). The intraobserver intraclass correlation coefficients were 0.82 and 0.95 for radiograph and MRI examinations, respectively. The interobserver intraclass correlation coefficients were 0.74 and 0.91, for radiograph and MRI examinations, respectively.

Second-Look Arthroscopy

Second-look arthroscopy was performed in patients who wanted the tibial Double-Spike Plate (Smith & Nephew Endoscopy) removed. Meniscal healing was classified as complete healing, partial healing, or failure, as described previously.[6,22] In brief, if there was no defect in the repaired meniscus, it was classified as complete healing (Figure 1C). If a partial-thickness defect was visible, it was classified as partial healing (Appendix Figure A1, available in the online version of this article). If there remained a large defect at the torn area, it was classified as failure to heal. Chondral status of the lateral femoral condyle and lateral tibial plateau was also evaluated according to International Cartilage Repair Society (ICRS) grading (Figure 1D). In addition, the chondral status in each location at the time of initial surgery was compared with that at second-look arthroscopy.

Statistical Analysis

The data are expressed as mean ± SD. Statistical analysis was performed with PASW Statistics (v 18; SPSS Inc). The Mann-Whitney U test was used to compare nonparametric variables between the groups. The chi-square test was used to compare the male:female ratio and the BTB:HS (graft) ratio. The ICRS grading at initial surgery and that at second-look arthroscopy were compared by the Wilcoxon signed rank test. Pearson correlation coefficients were calculated for analyzing factors affecting chondral injuries. Significance was defined as $P < .05$.

RESULTS

Patient data are shown in Table 1. There were no significant differences in age at surgery, male:female ratio, time from injury to surgery, follow-up time, and graft selection (BTB or HS) between the study and control groups ($P > .05$). None of the patients showed pain, loss of range of motion, or swelling in the affected knee, and KT-1000 side-to-side differences were 0.34 ± 1.77 mm and 0.13 ± 1.32 mm, respectively (P = .52), at last follow-up.

Radiographs showed no lateral joint space narrowing in the study and control groups, and there was no significant difference (P = .63) (Table 2). On MRI, although there was no significant difference in the progression of coronal extrusion between the groups (P = .23), sagittal extrusion progressed significantly in the study group (P = .0004). In the study group, the all-inside repair was performed in 12 patients, and the inside-out repair was performed in 29 patients. Coronal extrusion and sagittal extrusion were 0.18 ± 0.81 mm and 1.57 ± 0.99 mm in the all-inside repair group and −0.29 ± 0.87 mm and 1.07 ± 1.69 mm in

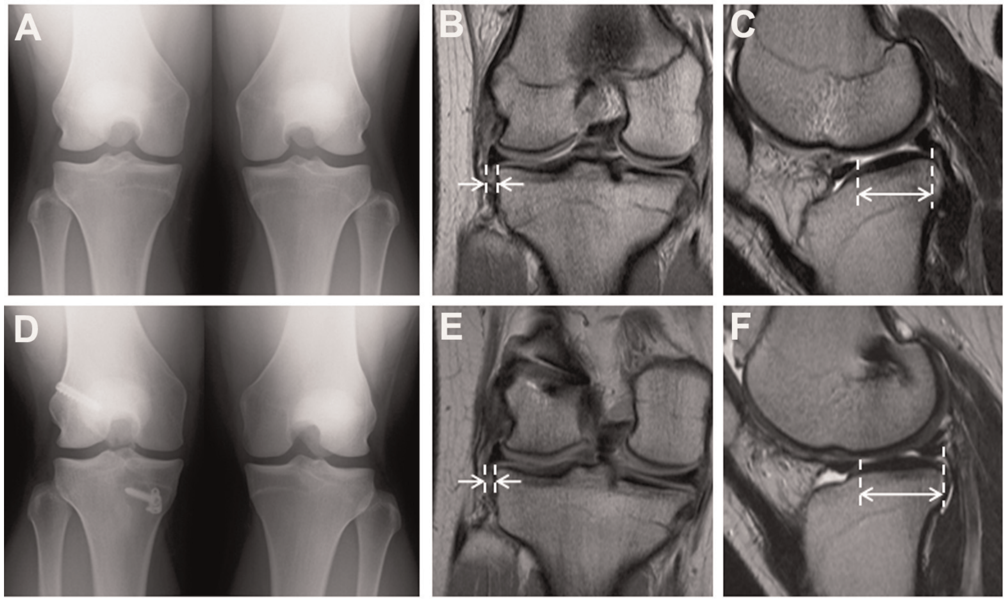

Figure 2. Pre- and postoperative images of a 16-year-old female patient (same as in Figure 1). (A) Lateral joint space on radiograph and (B) coronal and (C) sagittal extrusion on magnetic resonance imaging are measured preoperatively. (D) Lateral joint space narrowing is 0.1 mm; (E) coronal extrusion is reduced at 1.5 mm; and (F) sagittal extrusion has progressed to 3.0 mm at 2 years postoperatively.

TABLE 1
Patient Data[a]

	Study Group	Control Group	*P* Value
Patients	41	98	
Age, y	29.5 (14-57)	27.1 (14-61)	.11
Sex, male:female	18:23	39:59	.65
BMI	23.6 (19.4-31.4)	23.2 (18.4-36.8)	.061
Time from injury to surgery, d	124.8 (26-1124)	193.8 (21-2922)	.68
Follow-up, y	3.4 (2-6.3)	3.9 (2-9.4)	.055
Graft, BTB:HS	25:16	50:48	.28

[a]Values are presented as mean (range) or n. BMI, body mass index; BTB, bone–patellar tendon–bone; HS, hamstring tendon.

the inside-out repair group, respectively. There were no significant differences between all-inside and inside-out repairs in the study group at >2 years after surgery (*P* = .167 and .334, respectively).

Second-look arthroscopy was performed in 30 patients in the study group. Eighteen patients obtained complete healing; 9 achieved partial healing; and 3 failed to heal (Table 3).

Chondral status in the lateral compartment was compared between the study and control groups, 66 patients of whom underwent second-look arthroscopy. Chondral status of the lateral femoral condyle was improved in 6, underwent no change in 22, and worsened in 2 in the study group, while it was improved in 7, underwent no change in 55, and worsened in 4 in the control group (Figure 3; Appendix Table A1, available online). There was no significant difference between the groups in the femoral condyle (*P* = .29). However, chondral status of the lateral tibial plateau was improved in 3, underwent no change in 9, and worsened in 18 in the study group, whereas it was improved in 4, underwent no change in 48, and worsened in 14 in the control group (Figure 4; Appendix Table A1, available online). Unlike the lateral femoral condyle, the lateral tibial plateau demonstrated a significant difference between the groups (*P* = .0011). However, chondral injury progression in the lateral tibial plateau in the study group did not seem to be associated with other factors, such

TABLE 2
Progression of Radiographic Outcomes Between the Groups[a]

	Study Group	Control Group	*P* Value
Radiograph: joint space narrowing, mm	−0.04 ± 0.8	0.0082 ± 1.0	.63
MRI: extrusion, mm			
Coronal	−0.16 ± 0.88	0.03 ± 0.62	.23
Sagittal	1.2 ± 1.54	0.32 ± 1.0	.0004

[a]Progression outcomes: the difference between the preoperative and final follow-up results. Values are presented as mean ± SD. MRI, magnetic resonance imaging.

TABLE 3
Healing Status in the Study Group

	Complete Healing	Partial Healing	Failure
Patients, n (%)	18 (60)	9 (30)	3 (10)

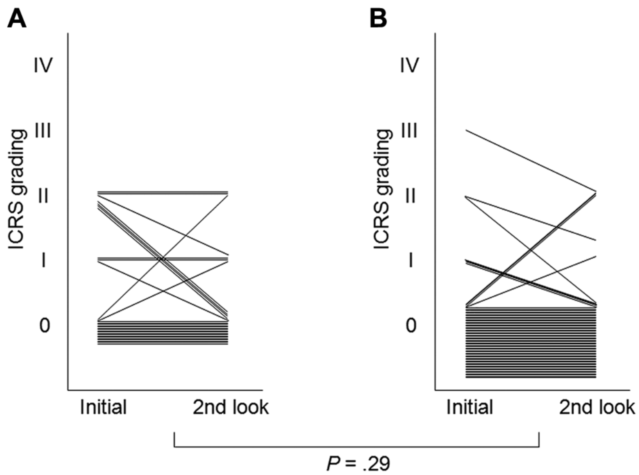

Figure 3. Chondral status of the lateral femoral condyle according to ICRS grading at initial surgery and second-look surgery. (A) Study group. (B) Control group. ICRS, International Cartilage Repair Society.

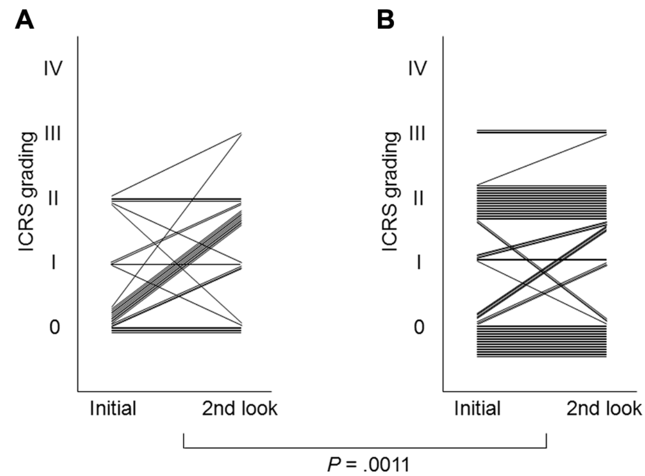

Figure 4. Chondral status of the lateral tibial plateau according to ICRS grading at initial surgery and second-look surgery. (A) Study group. (B) Control group. ICRS, International Cartilage Repair Society.

as age, BMI, time from injury to surgery, meniscal healing, lateral joint space on radiograph, and coronal/sagittal extrusion on MRI (Appendix Table A2, available online).

DISCUSSION

The most important finding of this study was that the study group showed no significant differences, including clinical findings, lateral joint space narrowing, and coronal extrusion, as compared with the control group at a mean 3.4 years postoperatively. Although sagittal extrusion progressed significantly in the study group, the amount of change was small, and the progression did not correlate significantly to chondral status. Interestingly, chondral lesions of the lateral tibial plateau in the study group were worsened despite the high healing rate after repair at the second-look arthroscopy 2 years after surgery.

Some studies showed that excellent clinical outcomes could be obtained by the posterior horn tear of the LM left in situ at the time of ACLR.[8,18] However, lateral joint space narrowing was significant at a mean follow-up of 10 years. In other words, it was shown that degenerative changes had progressed gradually. A previous study showed that radial tears have a low intrinsic cell density and limited ability to provoke the stimulus for biological repair.[10] In addition, biomechanical studies showed that a posterior horn tear of the LM increased peak contact pressure.[4,7,16] Furthermore, even though the pullout technique was performed in those reports, the repair procedure could normalize the contact pressure down to almost normal values and restore knee stablity.[21] Thus, these findings suggest that radial/flap tears of the posterior horn of the LM should be repaired, since the previous report concluded that repair should be attempted to restore the hoop tension of the LM.[3]

In vivo function of the meniscus is generally investigated by clinical findings and radiograph and MRI examinations. On clinical examination, knee pain, joint line tenderness, and McMurray test are helpful for detecting a meniscal tear,[3] but a posterior horn tear with an ACL tear rarely causes such findings and has no specific symptoms. Radiograph is a standard examination for evaluating joint space width and any degenerative changes. In addition, radiograph is the only simple test to perform an evaluation under a loading condition, such as the Rosenberg view, which has been described to be more sensitive than full extension to assess joint space narrowing.[17] MRI is an important examination to detect an abnormal lesion in the meniscus; however, a repaired meniscus cannot be fully evaluated by conventional MRI.[14,24] Thus, computed tomography arthrography or magnetic resonance arthrography is useful for assessing residual tear after repair,[2,9,13] although arthrography was not performed in the present study. In recent years, meniscal extrusion on MRI has been reported to be an important finding for remaining meniscal function, especially in root/horn tears.[9] In many reports, meniscal extrusion was evaluated only in coronal images, but the meniscus extrudes in a radial direction. Thus, measuring not only coronal extrusion but also sagittal extrusion should be required, as in the previous report.[1] More detailed assessment of meniscal tears, such as tear patterns, tear lengths, and stability, can be evaluated only by arthroscopy. In addition, arthroscopic assessment has become the gold standard for evaluating the healing status of the meniscus.[11] Therefore, meniscal function was comprehensively evaluated with all these procedures in the present study.

No previous study has evaluated lateral joint space narrowing after repair of the posterior horn tear of the LM at the time of ACLR. Regarding such tears being left in situ, 2 previous studies showed postoperative lateral joint space narrowing. Lee et al[8] reported narrowing of 0.33 mm at

3 years postoperatively, and Shelbourne et al[18] showed narrowing of 1.0 mm at a mean follow-up of 10 years. The current study showed that the amount of change was only 0.04 mm at a mean 3.4 years postoperatively; thus, an excellent radiologic result was obtained by repairing the tears. This satisfactory result of weightbearing radiograph, the only test performed under the loading condition, indicates the necessity of the repair procedure rather than the tear being left in situ.

MRI evaluation after repair of the posterior horn tear of the LM with ACLR was analyzed in only 1 report. It should be noted that no report investigated meniscal extrusion when the tears were left in situ. Ahn et al[1] reported that the displaced LM was reduced, mainly in the sagittal plane, at a mean follow-up of 8.7 months after surgery. However, the current study showed that coronal extrusion did not change, but sagittal extrusion progressed significantly as compared with the control group. This conflicting result might be due to the difference in the time of the follow-up MRI. In the previous study, follow-up MRI was evaluated at a mean 8.7 months, whereas in the current study, it was evaluated at a mean 3.4 years. Thus, it is speculated that LM could be reduced by repair in the early phase, but extrusion might progress gradually over the midterm. Strictly speaking, this may suggest that meniscal function cannot be completely normalized even by side-to-side repair. A more robust suturing technique may be needed.

Although previous studies have included small numbers of patients, meniscal healing rate have been reported after radial/flap tears of the posterior horn of the LM were repaired with ACLR and evaluated by second-look arthroscopy. Ahn et al[1] reported on 9 patients who underwent second-look arthroscopy: 8 had complete healing and 1 had incomplete healing at a mean follow-up of 21.3 months after the first surgical procedure. Song et al[20] reported that, of 15 patients, 9 (60%) had healed completely, 4 (27%) had healed partially, and 2 (13%) had failed to heal at a mean follow-up of 24 months. These results were comparable with the current study. When compared with a study reporting the healing rate of repaired isolated radial tears of the midbody of the LM, which achieved complete or partial healing in only 61% of cases,[22] the current study achieved an excellent healing rate of 90%. Despite the fact that the capacity of the radial tear to heal was low, stability acquired by repair and bone marrow bleeding from bone tunnels with concomitant ACLR could enhance the healing of the tear.

Clinical outcomes and radiograph and MRI examinations are standard methods of analyzing meniscal function, but evaluating changes of cartilage lesions is also an objective method to analyze meniscal function from the perspective of protecting articular cartilage. Understandably, there is a need to keep in mind that cartilage deterioration is multifactorial and related not only to meniscal tears but also to ligament instability or osteochondral sequelae of bone bruises. To the best of our knowledge, none of the previous studies has shown the changes of the lateral compartment chondral status arthroscopically after repair of radial/flap tears of the posterior horn of the LM with ACLR. Interestingly, as compared with the control group, cartilage lesions in the study group did not differ from the first surgical procedure at the lateral femoral condyle, but those at the lateral tibial plateau worsened significantly at 2 years postoperatively. The reason might be that the first injury had already caused a more critical effect on the lateral tibial plateau since it caused the radial/flap tears of the posterior horn of the LM. Additionally, the result—that meniscal position was almost restored and no correlation was detected among clinical and radiologic variables in the present study—may indicate that the first injury affects the fate of the chondral status. Although there was no sign of roentgenographic osteoarthritis in the current study, careful observation should be continued for the long term.

There are some limitations in the present study. First, meniscal function, including the meniscofemoral ligament (MFL), could not be investigated. Cadaveric studies showed that the prevalence of the MFL is as high as 69%, and in the present study, the MFL was identified in 23 patients of the study group and 63 patients of the control group on MRI. In addition, the MFL is difficult to assess arthroscopically.[4] Thus, the focus was on evaluating the posterior horn of the LM. Second, the results of LM repair and the results of LM tears left in situ could not be compared. Although there is no biomechanical study of side-to-side repair with an all-inside or inside-out suture technique for radial/flap tears of the posterior horn of the LM, pullout repair for root tears has already been demonstrated to maintain meniscal function. It seemed rational to repair the posterior tear of the LM to stabilize the torn edge. Third, there is a possibility that the magnitude of the effect at first injury differed between the study and control groups. The cartilage injury was assessed arthroscopically, but the quality of the cartilage could not be fully assessed. Therefore, evaluating the quality of the cartilage with T2 mapping or T1ρ MRI is needed in the next study. Fourth, total leg alignment was not evaluated. Thus, it is unclear whether leg alignment correlates with meniscal healing. Finally, the length of follow-up may be too short to detect radiographic regenerative changes.

CONCLUSION

The clinical and radiographic outcomes after repair of radial/flap tears of the posterior horn of the LM combined with anatomic ACLR were successful and comparable with those after isolated ACLR without any other injuries at a mean 3.4 years postoperatively, except for sagittal extrusion on MRI. Chondral lesions of the lateral tibial plateau worsened regardless of meniscal healing at 2 years postoperatively. Surgeons should keep in mind that chondral injuries might progress over the midterm.

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