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Acute Grade III Medial Collateral Ligament Injury of the Knee Associated with Anterior Cruciate Ligament Tear

The Usefulness of Magnetic Resonance Imaging in Determining a Treatment Regimen

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Background: The appropriate management of acute grade III medial collateral ligament injury when it is combined with a torn anterior cruciate ligament has not been determined.
Hypothesis: Magnetic resonance imaging grading of grade III medial collateral ligament injury in patients who also have anterior cruciate ligament injury correlates with the outcome of their nonoperative treatment.
Study Design: Prospective cohort study.
Methods: Seventeen patients were first treated nonoperatively with bracing. Eleven patients with restored valgus stability received anterior cruciate ligament reconstruction only, and six with residual valgus laxity also received medial collateral ligament surgery.
Results: Magnetic resonance imaging depicted complete disruption of the superficial layer of the medial collateral ligament in all 17 patients and disruption of the deep layer in 14. Restoration of valgus stability was significantly correlated with the location of superficial fiber damage. Damage was evident over the whole length of the superficial layer in five patients, and all five patients had residual valgus laxity despite bracing. Both groups had good-to-excellent results 5 years later.
Conclusions: Location of injury in the superficial layer may be useful in predicting the outcome of nonoperative treatment for acute grade III medial collateral ligament lesions combined with anterior cruciate ligament injury.

The medial collateral ligament (MCL), the major static stabilizer of the medial side of the knee joint,[20] is one of the most commonly injured ligament structures of the knee.[1] Therefore, it is important to establish optimal treatment for MCL injuries.

Nonoperative treatment has been recommended as the method of choice for grade I and grade II acute injuries of the MCL, and excellent or good results have been reported.[4,8] On the basis of the results of experimental and clinical studies, the current trend for acute grade III injuries is also nonoperative treatment.[5,6,14,21] However, there has been limited information regarding the appropriate management of acute grade III MCL injury when it is combined with a torn ACL. Shelbourne and Porter[17] compared different surgical methods for combined ACL and MCL injuries: ACL reconstruction only and ACL reconstruction with MCL repair. The authors found no difference in valgus laxity between the two groups, and the patients who also had MCL repair reported more knee stiffness. The authors concluded that reconstruction of the ACL is sufficient to restore knee stability and that limited surgery may facilitate functional rehabilitation. However, there have been no studies to test whether all acute inju-

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ries of the MCL can be treated nonoperatively when combined with a torn ACL that has been surgically repaired.

Magnetic resonance imaging is acknowledged as the appropriate diagnostic tool for the evaluation of internal derangement of the knee. Specifically, MRI is useful for the detection of ligament injury and provides information regarding the location as well as the severity of injury. Extensive studies have been published with regard to the evaluation of the cruciate ligaments by using MRI. The number of MRI studies on MCL injuries, however, has been limited. The focus of those studies was mainly the correlation between grading of injury by MRI and clinical grading at the time of injury to test the efficacy of MRI for diagnosis of MCL injury.[3,13,15]

We hypothesized that such classic MRI grading of associated grade III MCL injury in patients who also had ACL injury would correlate with the outcome of their nonoperative treatment. To test this hypothesis, we used MRI to evaluate patients with acute grade III MCL injury combined with a torn ACL. The patients then underwent nonoperative treatment for 6 weeks with bracing. The purpose of this study was to clarify whether MRI was useful in predicting the outcome of nonoperative treatment.

MATERIALS AND METHODS

Between February 1995 and December 1997, 17 consecutive patients with combined acute ACL and grade III MCL injuries were treated by the same physician at our institute. Inclusion criteria in this study were 1) a history of knee injury within 3 weeks of the first examination, 2) a positive Lachman sign (more than 1+), and 3) a clinically unstable valgus stress test at both 0° and 30° of flexion with an indefinite or absent end point (grade III injury). Grading of MCL injuries was determined according to the classification of the American Medical Association[2] with a modification by Fetto and Marshall.[6] Patients who had mechanical locking of the knee at the time of the first examination were not included in the study. The patients (15 men and 2 women) ranged in age from 15 to 31 years (mean, 22.8); their activity at the time of injury is listed in Table 1. The initial interval from the time of injury to the first examination ranged from 0 to 20 days (mean, 6.7), and the interval from injury to MRI ranged from 0 to 28 days (mean, 13.3).

Magnetic resonance imaging was performed with a Hitachi Medical Corporation 0.3-T AIRIS system (Hitachi Electronics, Tokyo, Japan). Coronal scans were obtained with the following parameters: 16-cm field of view; 256 × 192 matrix; 4.0- to 5.0-mm slice thickness with a 1.5-mm interslice gap; repetition time (TR), 267 ms; echo time (TE), 20 ms. The spin echo images were made with a TR of 500 ms and a TE of 15 ms. The gradient echo images were made with a TR of 336 ms, TE of 4 ms, and a 90° flip angle. Images of MCL injuries in the patients were first graded as previously reported (Table 2).[13] This classic grading method specifically focused on the disruption of both the superficial and deep layers of the MCL. Disruption of the superficial layer was depicted by the presence of an intermediate signal on spin echo images and a high signal on gradient echo coronal images across the entire width of this layer.

The evaluation was performed on two or three successive coronal images. Disruption of the deep layer was identified by the presence of fluid (intermediate signal on spin echo images and high signal on gradient echo coronal images) extravasating from the knee joint through the deep layer (meniscotibial or meniscofemoral ligament) into the periligamentous tissue (between the superficial layer and femoral condyle/tibial plateau). However, on the basis of a study demonstrating that the superficial layer of the MCL is a major stabilizer against valgus stress,[7] we further classified MRI of the MCL injury into three types according to the location of the disruption of the superficial layer. In a type I injury, the disruption was localized at the femoral attachment site; in a type II injury, the disruption was localized at the tibial insertion site; and in

TABLE 1
Background Information on 17 Patients with Acute ACL and MCL Injuries

Sex	Age at injury (years)	Cause of injury	Initial interval to our clinic (days)	Initial interval to MRI (days)
M	31	Baseball	0	14
M	26	Traffic accident	6	9
F	21	Volleyball	14	18
M	15	American football	20	26
M	26	American football	1	12
M	16	American football	0	0
M	19	American football	1	10
F	21	Skiing	8	4
M	28	Skiing	2	8
M	27	Skiing	10	21
M	22	American football	0	28
M	20	Skiing	14	24
M	25	Judo	20	24
M	31	Skiing	2	2
M	20	American football	1	3
M	25	Skiing	10	14
M	15	Rugby	5	9

TABLE 2
Classic Method of Grading MCL Injury by MRI[13]

Grade	MRI findings
I (Minor tearing of ligament fibers)	Periligamentous swelling without complete disruption of superficial or deep layer
II (Complete disruption of superficial layer)	Periligamentous swelling with complete disruption of superficial layer
III (Complete disruption of superficial and deep layer)	Same as grade II but with fluid extravasating from the joint into the periligamentous tissue

a type III injury, the disruption was evident over the whole length of the superficial layer.

The presence of occult fractures (bone bruises) was identified by diminished signal intensity on spin echo images and by increased signal intensity on gradient echo images in the subcortical bone.[11,19] Meniscal injuries were first evaluated by MRI as linear, globular, or combined high signal intensity on spin echo and gradient echo images that extended to at least one articular surface of the meniscus.[18] We confirmed the meniscal tears by arthroscopic examination at the time of ACL reconstruction, as well as the presence of chondral lesions corresponding to bone bruises (Outerbridge classification[12]).

All of the patients followed the same treatment regimen: initial bracing for 6 weeks to prevent valgus forces, while allowing full weightbearing on the injured lower extremity and thigh muscle training. Every patient started bracing at the first clinic visit. This nonoperative treatment was followed by surgical reconstruction of the ACL performed with autogenous hamstring tendon. Whether to add surgical reconstruction of the MCL was determined according to the residual valgus laxity of the knee, as demonstrated by a stress radiograph obtained with the patient under general anesthesia before ACL reconstruction. When the side-to-side difference in the medial joint opening was more than 4 mm at 0° of knee flexion, we added MCL reconstruction or MCL advancement at the time of ACL reconstruction. For MCL reconstruction, we anatomically reconstructed the superficial layer with an autogenous or allogenic iliotibial tract (fascia lata) graft (S. Horibe et al., unpublished data, 1999). We added no treatment for the deep layer.

The clinical follow-up evaluation was performed an average of 64 months after surgery (range, 48 to 74 months). An overall subjective score was compiled for each patient by using the International Knee Documentation Committee (IKDC) evaluation form. According to the IKDC knee evaluation criteria, patients' knees were rated as normal, nearly normal, abnormal, or severely abnormal. The evaluation was performed on 16 of 17 patients; 1 patient in the ACL/MCL group was hospitalized with a severe illness and could not be evaluated. Instrumented testing of anterior-posterior laxity was performed with the KT-2000 arthrometer (MEDmetric Corporation, San Diego, California), and the side-to-side difference at manual maximum force was reported for comparison. For the evaluation of valgus laxity, a stress test with the patient awake was performed at 30° of knee flexion, and the side-to-side difference was graded according to the IKDC form (0 to 2 mm, 3 to 5 mm, 6 to 10 mm, and >10 mm). Joint laxity measurement was performed on 13 of 17 patients. Three patients (two in the ACL group and one in the ACL/MCL group) could not visit our clinic because they had moved away, and the one patient in the ACL/MCL group could not be measured because of hospitalization.

Fisher's exact test was performed to analyze the correlation of the two different MRI classifications for the MCL lesion with the presence of bone bruises, meniscal tears, and restoration of valgus stability. The Mann-Whitney U-test was performed to investigate the difference in the degree of chondral damage, IKDC subjective scoring, and side-to-side difference in the medial joint opening between the ACL group and the ACL/MCL group. The difference between the groups in anterior-posterior laxity as measured by a KT-2000 arthrometer was evaluated with the Student's t-test. Statistical significance for all three tests was set at $P = 0.05$.

RESULTS

Classification of MCL Lesions by MRI

According to the classic MRI grading method, 3 of 17 MCL lesions (18%) were grade II (complete disruption of the superficial layer but not of the deep layer) (Fig. 1A), and 14 (82%) were grade III (complete disruption of both the

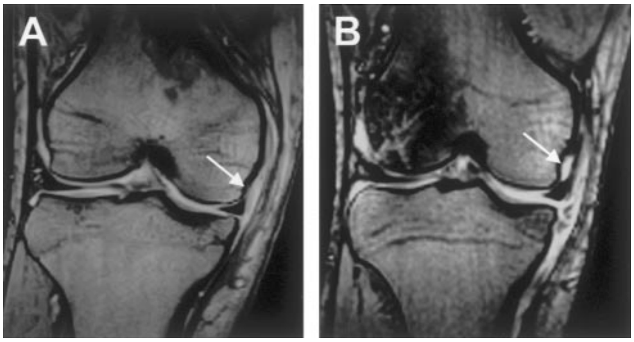

Figure 1. Coronal gradient echo images of grade II (A) and grade III (B) MCL injuries. High signal image crossed the entire width of the superficial layer of the MCL in both cases, suggesting the complete disruption of the superficial layer. Fluid (high signal) extravasating from the knee joint into the periligamentous tissue, corresponding with complete disruption of the deep layer, is well depicted in the grade III injury (B, arrow), but not in grade II injury (A, arrow).

superficial and deep layers) (Fig. 1B) (Table 3). No grade I MCL lesions were found among the patients in the study.

When MCL injuries were classified by the location of the injury in the superficial layer, 12 of 17 lesions (71%) were classified as type I (located at the femoral attachment site) (Fig. 2, A and B), and 5 (29%) as type III (the lesion was extended from the femoral attachment site over the joint line) (Fig. 2, C and D). There were no type II injuries (lesion located at the tibial insertion site) (Table 3).

Bone Bruises and Chondral and Meniscal Lesions

Ten of 17 patients had bone bruises at the lateral femoral condyle or the lateral tibial plateau or at both sites. Arthroscopic examination revealed that there were 3 grade I, and 2 grade II chondral lesions at the surface of the femoral condyle with a bone bruise, and 12 patients had an intact chondral surface. There were two grade I, two grade II, and one grade III lesions at the surface of the tibial plateau with a bone bruise. Twelve patients had an intact chondral surface on the tibia.

None of the patients had a medial meniscal tear, and seven patients had a lateral meniscal tear (Table 3). Arthroscopic examination revealed that one T-type tear was at the posterior horn, four partial longitudinal tears were at the tibial side of the posterior horn, and two radial tears were found at the midportion.

Nonoperative Treatment for MCL Injury

Eleven of 17 patients regained valgus stability after nonoperative treatment (side-to-side difference in the medial joint opening of less than 4 mm at 0° by stress radiography under general anesthesia); however, 6 patients did not. The relationship between the two different MRI classification methods and the outcome of nonoperative treatment was evaluated (Table 3). By the classic MRI grading, 8 of 14 patients with grade III lesions (57%) regained medial stability through bracing; however, 6 patients (43%) had residual valgus laxity. All three patients with grade II lesions regained medial stability. Statistical analysis showed no significant correlation between the MRI grading and the restoration of valgus stability ($P = 0.5147$).

When MCL lesions were classified by the location of the disruption of the superficial layer, 11 of 12 patients with type I lesions (92%) regained medial stability and only 1 patient (8%) had residual valgus laxity after nonoperative treatment. Among the five patients with type III lesions, however, none regained valgus stability. There was a significant correlation between the injury type and restoration of valgus stability ($P < 0.0010$).

There was no significant correlation between the restoration of valgus stability and the presence of bone bruises, the degree of chondral lesions at the lateral femoral condyle, or the degree of chondral lesions at the lateral tibial plateau ($P = 0.3043$, $P = 0.8016$, and $P = 0.5465$, respectively). There was no significant correlation between the restoration of valgus stability and the presence of or the type of lateral meniscal tear ($P > 0.9999$ and $P = 0.5465$, respectively).

MCL Surgery and Operative Findings

The mean side-to-side difference in the medial joint opening among the patients who had ACL reconstruction and MCL surgery (ACL/MCL group) was 4.8 mm (range, 4 to

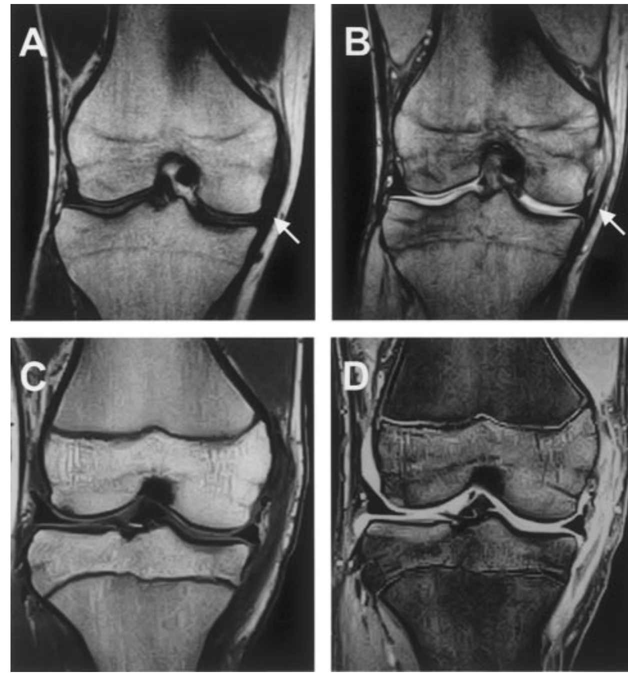

Figure 2. Coronal images of type I (A and B) and type III (C and D) MCL injuries. The superficial fiber, which is depicted as low signal image on spin echo (A, arrow) and gradient echo (B, arrow) images, is interrupted by high signal image at the femoral attachment site in type I MCL injury. In contrast, interruption of the superficial fiber by high signal image is observed throughout the length of the fiber in type III MCL injury.

TABLE 3
MRI Findings and Results of Nonoperative Treatment

MRI grade	Injury location by MRI	Bone bruise	Medial meniscal tear	Lateral meniscal tear	Residual valgus instability after bracing
III	III	+	−	−	+
III	III	+	−	−	+
III	I	+	−	−	−
III	III	+	−	+	+
III	I	+	−	−	+
III	I	−	−	+	−
II	I	+	−	−	−
II	I	−	−	−	−
II	I	−	−	−	−
III	I	+	−	+	−
III	III	+	−	+	+
III	I	+	−	+	−
III	I	−	−	+	−
III	I	−	−	−	−
III	I	+	−	+	−
III	I	−	−	−	−
III	III	−	−	−	+

7) at 0° of knee flexion and 6.6 mm (range, 5 to 12) at 30° of knee flexion. Among patients who received only ACL reconstruction (ACL group), the mean side-to-side difference in the medial joint opening was 0.7 mm (range, 0 to 2) at 0° and 2.5 mm (range, 0 to 4) at 30° of knee flexion. Duration of time from the initial injury to the reconstruction surgery ranged from 41 to 427 days (average, 118).

At the time of operation of the six patients who required MCL surgery because of residual valgus laxity, we evaluated the healing MCL to correlate the surgical pathologic findings and the preoperative MRI findings. In five of six lesions that were graded as type III by injury location, the superficial MCL remnant was thin and had scar-like tissue along the whole length (Fig. 3, A and B). In contrast, in one case, which was graded as type I, the superficial remnant of the MCL looked like normal tissue; however, its femoral insertion site was located anterior to the original femoral insertion of the MCL on the medial epicondyle. The deep MCL was thin and lax in all cases (Fig. 3C). In the five patients with type III lesions, we reconstructed the MCL superficial layer with autogenous or allogenic iliotibial tract graft (Fig. 3D). In the one patient with a type I lesion, we advanced the femoral insertion site of the superficial remnant to the original femoral insertion site of the MCL. Treatment of the deep layer of the MCL was not required in any case.

Outcome

Clinical evaluation was performed at an average of 5 years after the operation. Among patients who received only ACL reconstruction (ACL group), 64% (7 of 11) graded their knee function as normal, and 36% (4 of 11) as nearly normal. Among patients who underwent reconstruction of both the ACL and the MCL (ACL/MCL group), 60% (3 of 5) graded their knee function as normal, and 40% (2 of 5) as nearly normal. There was no significant difference between the ACL and the ACL/MCL group ($P = 0.9098$). The KT-2000 arthrometer data for anterior-posterior laxity at manual maximum stress were available for 9 of 11 patients (82%) in the ACL group and for 4 of 6 patients (67%) in the ACL/MCL group. The mean side-to-side difference in the ACL group was 1.33 ± 1.32 mm, and in the ACL/MCL group, 2.25 ± 1.89 mm. There was no significant difference between the two groups ($P = 0.3310$). Valgus laxity testing showed that 78% (7 of 9) of patients in the ACL group had a side-to-side medial joint opening of 0 to 2 mm and 22% (2 of 9) had an opening of 3 to 5 mm. In the

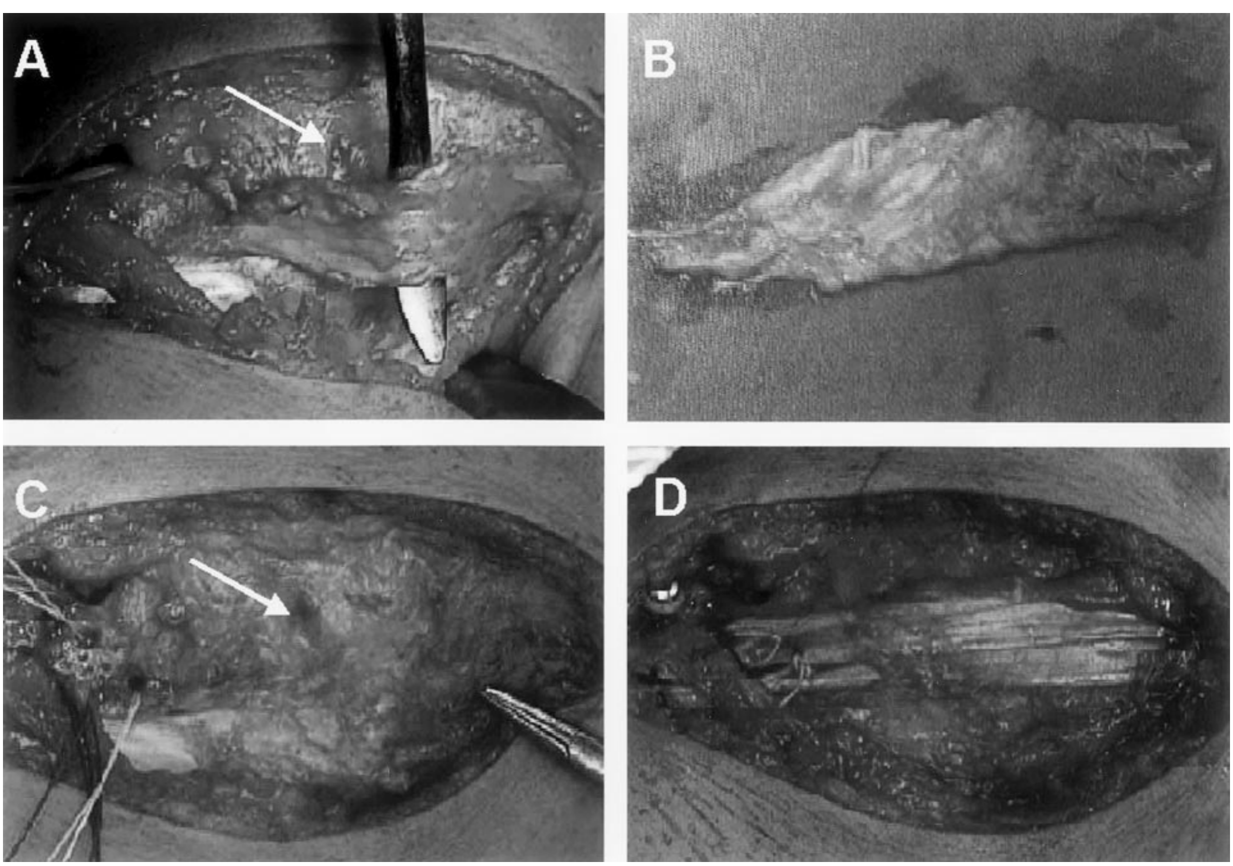

Figure 3. A, intraoperative photo of the superficial MCL at the time of MCL reconstruction. The superficial layer is thin and lax. The arrow indicates joint line level. B, excised specimen of the superficial MCL. The superficial layer is thin and consists of disorganized collagenous matrix. C, the deep layer of the MCL exposed after excision of the superficial layer. The deep fiber is also thin and lax at joint line level (arrow). D, reconstruction of the superficial MCL with the autogenous iliotibial tract graft.

ACL/MCL group, 75% (3 of 4) of patients had a side-to-side medial joint opening of 0 to 2 mm, and 25% (1 of 4) had an opening of 3 to 5 mm. There was no significant difference between the two groups ($P = 0.9385$).

DISCUSSION

The results of this study demonstrated the usefulness of MRI in predicting the outcome of nonoperative treatment for acute grade III MCL lesions combined with a torn ACL. By the classic method of grading MCL injury, all of the patients with grade II injuries were successfully treated nonoperatively, and all those for whom nonoperative treatment was unsuccessful had grade III injuries. This result implies a correlation between the outcome of nonoperative treatment and the MRI grade; nonetheless, statistical analysis showed no significant correlation. The sample size might have been too small for statistical power; thus, the reliability of classic MRI grading in predicting the outcome of nonoperative treatment would need to be verified with a larger sample size.

However, because all of the cases were clinically classified as grade III, which suggests complete rupture of the ligament substance (unstable to valgus stress with an indefinite or absent end point), both superficial and deep MCL fibers were presumed to be ruptured. In fact, surgical exposure revealed that all six patients who received MCL surgery had complete ruptures of the deep layer. However, all of the cases were not classified as grade III lesion by the classic MRI grading method. In the three grade II cases, rupture of deep fibers was not confirmed. The deep layer is not always depicted with use of the current MRI protocol. Thus, fluid extravasating from the knee joint into the periligamentous tissue was used in the present study as an indirect sign of complete disruption of the deep layer. Although this sign is easily seen on a gradient echo coronal image when there is enough effusion within the joint, it is difficult to depict the disruption of the deep layer when there is little joint effusion. In the present study, none of the three grade II cases had enough joint effusion to show high signal intensity around the medial joint compartment on a gradient echo image (Fig. 1). Therefore, the disruption of the deep layer might have been missed by this indirect MRI evaluation method. Use of more sensitive methods to depict soft tissue edema, such as T2-weighted fat-suppressed images, would help to more accurately characterize damage in the deep layer.

We evaluated the presence of bone bruises, chondral lesions corresponding to the area of bone bruises, and the presence and type of lateral meniscal tears in all cases as potential indicators of the magnitude of valgus stress exerted on the knee joint at the time of injury. However, none of them were correlated with the restoration of valgus stability. Therefore, neither the presence of osteochondral damage nor meniscal injury, assessed by MRI, appears to help predict restoration of medial knee stability by nonoperative treatment.

When MCL lesions were classified according to the location of the disruption of the superficial layer, there was a significant difference in the result of nonoperative treatment among the types. All of the MCL lesions in the present study involved "complete" disruption of the superficial layer as seen on MRI scans. Nonetheless, most of the type I MCL lesions were successfully treated nonoperatively, whereas none of the type III lesions were. In the one case of type I injury that required surgical advancement, the superficial remnant of the MCL looked like normal tissue; however, its femoral insertion site was shifted anteriorly from the original femoral insertion of the MCL. We inferred that the femoral insertion peeled off and the torn end of the MCL remnant displaced anterior to the original femoral insertion site. This displacement could have caused the change in the femoral insertion site of the superficial MCL, leading to the failure to regain valgus stability. The femoral insertion site was not exposed in the other 11 type I cases, which were successfully treated without surgery. Without operative evidence, we speculated that there is usually little displacement of the remnant from the original injured site when the superficial layer of the MCL is torn at the femoral insertion site and, thus, that the superficial layer heals functionally without changing its anatomic orientation. Operative findings revealed that, in all five cases of type III injury, the superficial MCL was thin and lax. Extensive damage to the superficial layer over the whole length might have resulted in healing of the superficial MCL with thin and nonfunctional scar tissue and in the failure of resistance against valgus stress.

When there was residual valgus laxity after nonoperative treatment, we added MCL surgery in addition to ACL reconstruction. The reason we added restoration of valgus stability at the time of ACL reconstruction was based on a previous experimental study that showed that the ACL is significantly more loaded when there is residual valgus laxity because of MCL insufficiency.[16] The results of this study, therefore, suggest that ACL reconstruction in a knee with residual valgus laxity might lead to stretching of the ACL graft from overloading. Because no patient who had residual valgus laxity was treated with ACL reconstruction alone, we cannot be sure that the MCL reconstruction was necessary for a clinically successful result. However, we can state that combined reconstruction in the ACL/MCL group brought about results comparable with those of isolated ACL reconstruction in the ACL group, with no evidence of an increased incidence of complications.

We advanced or anatomically reconstructed the MCL superficial layer by using autogenous or allogenic iliotibial tract graft (fascia lata) in patients in whom there was residual valgus laxity. Operative findings showed that the deep layer of the MCL was thin and lax in all cases; nonetheless, we treated only the superficial layer. We speculated that, after secure reconstruction of the superficial MCL, the deep layer adjusts its matrix organization with that of the superficial graft over time after surgery. This speculation is based on basic research studies showing that tendon or tendon graft that was once artificially loosened in vivo by stress deprivation becomes free of loosening with time by thickening its own matrix. Histologically, once-disorganized matrix has been noted to restore its matrix organization to align longitudinally with the original axis of the tendon.[9,10] In the present study, we obtained satisfactory clinical results from MCL reconstruction in terms of either restoration of valgus stability or by IKDC subjective assessment in all cases. Therefore, we believe that anatomic reconstruction of the superficial MCL could be a sufficient method for obtaining a good clinical outcome, including the restoration of medial stability.

In summarizing all these results, the prognostic significance of the classic MRI grading of MCL injury was not verified in this study. All of the patients with grade II injuries were successfully treated nonoperatively, whereas all those who required MCL surgery had grade III injuries. The sample size was, however, not large enough for statistical power. Further analysis with a larger sample size will be required. Superficial MCL appearance on MRI is currently the best predictor of the prognosis for MCL lesions combined with ACL injury. Specifically, diffuse injury to the superficial layer was correlated with poorer outcome of nonoperative treatment for the MCL injury in terms of residual valgus laxity. Therefore, this new classification for categorizing MCL injuries by MRI according to location of the superficial MCL injury could be used to determine the treatment regimen for patients with a grade III MCL lesion combined with an ACL injury.

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