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Association between magnetic resonance imaging characteristics and pathological findings in entire posterior cruciate ligament with mucoid degeneration

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Abstract

Magnetic resonance imaging (MRI) findings of a tram-track appearance and celery stalk appearance in mucoid degeneration of the cruciate ligament are valuable; however, their pathological basis is unclear. Because these appearances are generally seen throughout the entire ligament, the association between MRI findings and pathological findings must be verified in specimens of the whole degenerated ligament, including the ligamentous attachments to bone. We herein report two cases of mucoid degeneration of the posterior cruciate ligament with osteoarthritis of the knee requiring total knee arthroplasty. The entire degenerated ligament, including the ligamentous attachments to bone, was removed and pathologically evaluated. On pathological examination, the central portion of the lesion showed typical mucoid degeneration, whereas the marginal and adherent portions showed normal ligament tissue, consistent with a tram-track appearance on T2-weighted MRI. The fibrous normal ligament tissues in the longitudinal direction in regions

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of mucoid degeneration were consistent with a celery stalk appearance on T2-weighted MRI. No mucoid degeneration was found in the attachment area. The tram-track appearance and celery stalk appearance of mucoid degeneration on MRI can be explained by the pathological findings.

Keywords
Mucoid degeneration, posterior cruciate ligament, total knee arthroplasty, magnetic resonance imaging, pathological finding, tram-track appearance, celery stalk appearance

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Introduction

Mucoid degeneration of the cruciate ligament, which was once difficult to diagnose, can now be diagnosed using modern diagnostic technology. The diagnostic approach is based primarily on imaging and physical findings. On magnetic resonance imaging (MRI), the tram-track appearance and celery stalk appearance in the ligament are well-known and valuable signs of mucoid degeneration. The clinical findings are characterized by knee pain, especially at extension and/or deep flexion, and a limited range of motion (ROM) of the knee.[1] In symptomatic cases that do not respond to conservative therapy, arthroscopic surgery is commonly performed to resect degeneration in the ligament, and the clinical outcome is reportedly favorable.[2] The tram-track appearance is characterized on T2-weighted MRI by high signal intensity at the center of the lesion in the affected ligament and linear low signal intensity at the limbus of the lesion. The celery stalk appearance is characterized on T2-weighted MRI by linear low signal intensity along the direction of the ligament fibers within the region of high central signal intensity. Although the definitive diagnosis of mucoid degeneration is based on the pathological findings, the exact association between these signs on MRI and the pathological findings is unclear. In addition, the pathological findings at the ligament attachments are unclear, although these appearances have been reported throughout the entire ligament in most affected patients.[3] In arthroscopic surgery for treatment of a degenerated ligament, the specimen submitted for pathologic examination is large enough to enable a definitive diagnosis but too small to verify an association with the imaging findings; therefore, a specimen of the whole ligament is required.

We herein report two cases of mucoid degeneration of the posterior cruciate ligament (PCL) combined with osteoarthritis (OA) of the knee requiring total knee arthroplasty (TKA), in which the entire ligament could be removed and pathologically evaluated. To the best of our knowledge, this is the first report on pathological evaluation of mucoid degeneration of the whole PCL, including the bony attachments, and the first investigation into the relationship of these pathological findings with the MRI appearances.

Case 1

A 72-year-old man visited our hospital with a 1-year history of left knee pain during walking and flexion of the knee. He had a history of atrial fibrillation and was being

treated with an anticoagulant. His body weight and body mass index were 99 kg and 35.9 kg/m^2, respectively. Physical examination revealed swelling of the knee, limitation of knee ROM (15°–130°), and tenderness at the medial joint line. He reported severe pain in his knee when the knee was deeply flexed. Radiographs of the knee showed loss of the medial tibiofemoral joint space and evidence of OA classified as Kellgren–Lawrence (KL) stage IV (Figure 1).

The femorotibial angle (FTA) was 185°. MRI revealed a tram-track appearance and celery stalk appearance: the whole ligament except the limbus had high signal intensity, and linear low signal intensity was present along the direction of the ligament fibers within the area of high signal intensity on T2-weighted imaging (Figure 2).

Based on these findings, the patient was diagnosed with knee OA with PCL mucoid

Figure 2. Lateral T2-weighted fat-suppression magnetic resonance imaging in Case 1 shows a tram-track appearance (white arrows) and celery stalk appearance (black arrow).

Figure 1. Anteroposterior and lateral radiographs in Case 1 show loss of the medial tibiofemoral joint space and stage IV osteoarthritis (Kellgren–Lawrence classification).

degeneration and treated surgically by fixed-bearing posterior-stabilized (PS) TKA (Persona; Zimmer Biomet, Warsaw, IN, USA). During the surgery, the PCL was separated into a block that included the bony attachments of the ligament on the femoral and tibial sides (Figure 3).

The extracted block was examined by a pathologist with 30 years of experience and stained with hematoxylin–eosin, Alcian blue/periodic acid-Schiff (PAS), and Elastica von Gieson. The pathological examination revealed mucoid degenerative tissue stained blue by Alcian blue, and this area had lost its normal fiber structure and was replaced by collagen fibers stained red by Elastica von Gieson (Figure 4).

The mucoid degenerative tissue was present in the central area of the ligament, and normal ligamentous tissue stained deep pink by PAS was in the marginal area (Figure 5), consistent with the tram-track appearance on MRI.

Notably, no areas in the ligament attachments were stained blue other than the cartilage on the surface of the femur, which was stained by Alcian blue (Figure 6).

In addition, fibrous normal ligamentous tissue stained deep pink by PAS was found in the center of the lesion within mucoid degenerative tissue that was stained blue by Alcian blue (Figure 7), consistent with the celery stalk appearance on MRI.

The pain on flexion disappeared immediately after the surgery, and the postoperative course was favorable. At 1 year after the surgery, the knee ROM was 0° to 130° and the knee pain was improved.

Case 2

A 76-year-old woman visited our hospital for evaluation of right knee pain during walking and on flexion of the knee. She had a history of diabetes that was being treated with oral medicine. In addition, she had undergone arthroscopic anterior

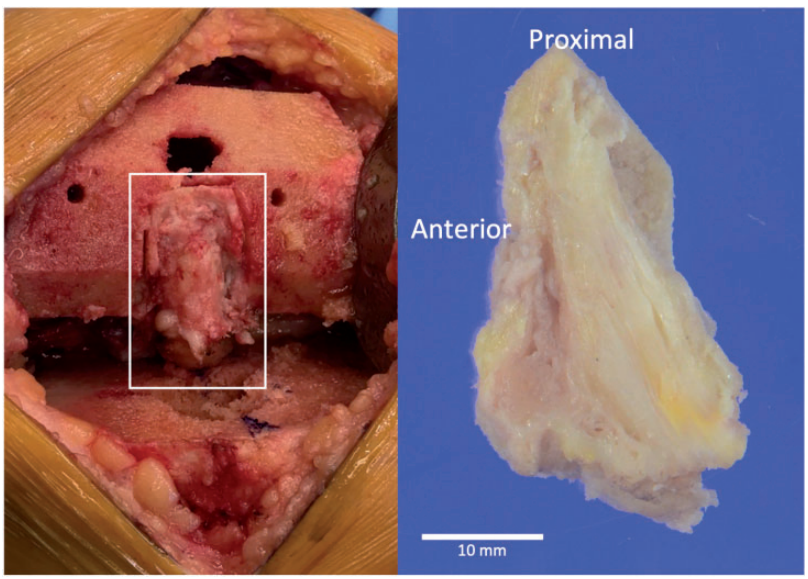

Figure 3. Intraoperative photograph (left) and cut surface of the resected (and formalin-fixed) posterior cruciate ligament (right) in Case 1. During surgery, the posterior cruciate ligament was excised in one block that included the bony parts of the femoral and tibial attachments (white rectangle).

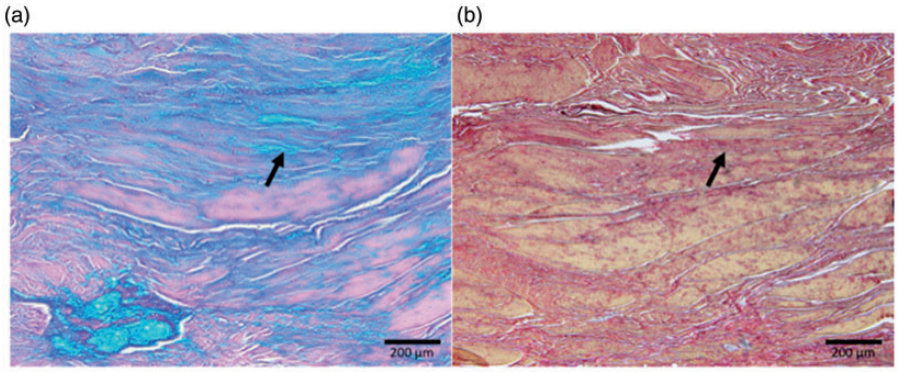

Figure 4. Histological slides of Case 1 show specimens of a part of the ligament stained by (a) Alcian blue/periodic acid-Schiff and (b) Elastica von Gieson. The pathological examination revealed mucoid degenerative tissue stained blue by Alcian blue (black arrow), and this area had lost its normal fiber structure and was replaced by collagen fibers stained red by Elastica von Gieson (black arrow).

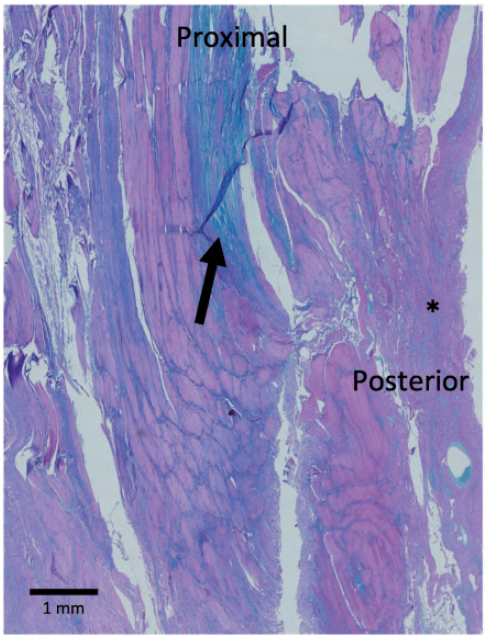

Figure 5. Histological slide of Case 1 shows Alcian blue/periodic acid-Schiff-stained specimens of the posterior marginal area of the ligament. Although the mucoid degenerative tissue was stained blue in a substantial part of the ligament (black arrow), almost no other areas were stained by Alcian blue in the posterior marginal area of the ligament (asterisk).

cruciate ligament (ACL) resection for ACL mucoid degeneration 17 years previously. Her body weight and body mass index were 68 kg and 27.7 kg/m^2, respectively. Physical examination revealed swelling of the knee, limitation of knee ROM (10°–130°), and tenderness at the medial femoral condyle. She reported pain in her knee during deep flexion. Radiographs of the knee showed arthropathic changes classified as Kellgren–Lawrence stage IV, and the FTA was 186° (Figure 8).

Similar to Case 1, MRI showed a tram-track appearance and celery stalk appearance as well as absence of the ACL. She was diagnosed with knee OA with PCL mucoid degeneration and treated by fixed-bearing PS TKA (Persona). The entire PCL was extracted after confirming absence of the ACL during surgery. The pathological findings of the PCL were the same as those in Case 1 (Figure 9).

As in Case 1, the pain on flexion disappeared immediately after the surgery, and the postoperative course was favorable. At 7 months postoperatively, the knee ROM was 0° to 130° and the patient reported no knee pain.

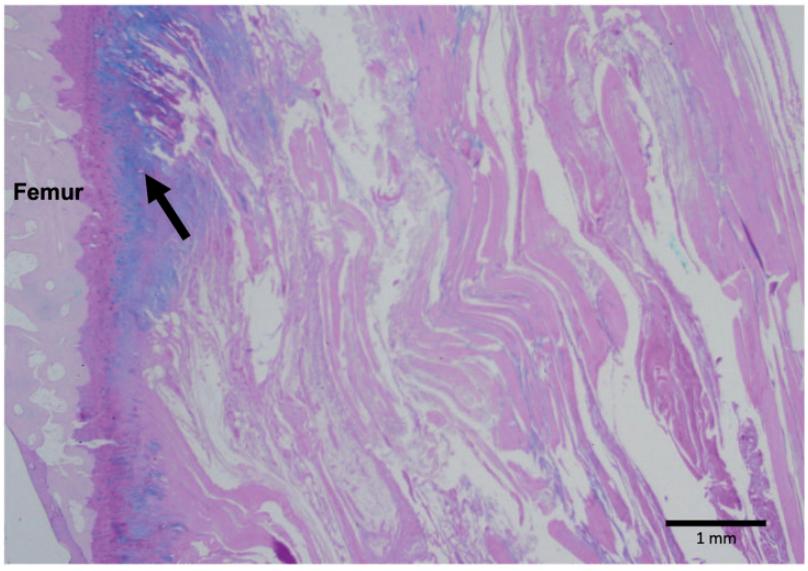

Figure 6. Histological slide of Case 1 shows Alcian blue/periodic acid-Schiff-stained specimens of the ligament attachment. Cartilage on the surface of the femur is stained blue by Alcian blue (black arrow), but no areas of the ligament attachments were stained by Alcian blue.

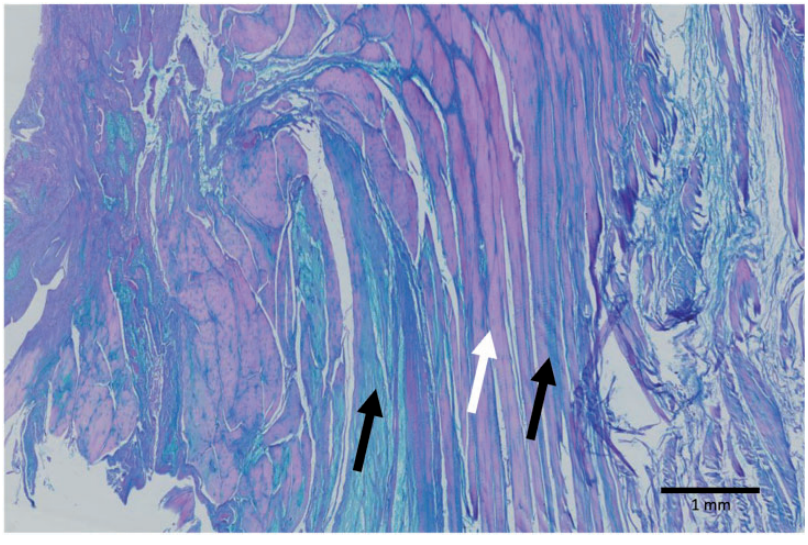

Figure 7. Histological slide of Case 1 shows Alcian blue/periodic acid-Schiff-stained specimens of a substantial part of the ligament. Normal fibrous ligamentous tissue stained deep pink by periodic acid-Schiff (white arrow) was found within mucoid degenerative tissue stained blue by Alcian blue (black arrows).

Figure 8. Anteroposterior and lateral radiographs in Case 2 show the loss of medial tibiofemoral joint space and stage IV osteoarthritis (Kellgren–Lawrence classification).

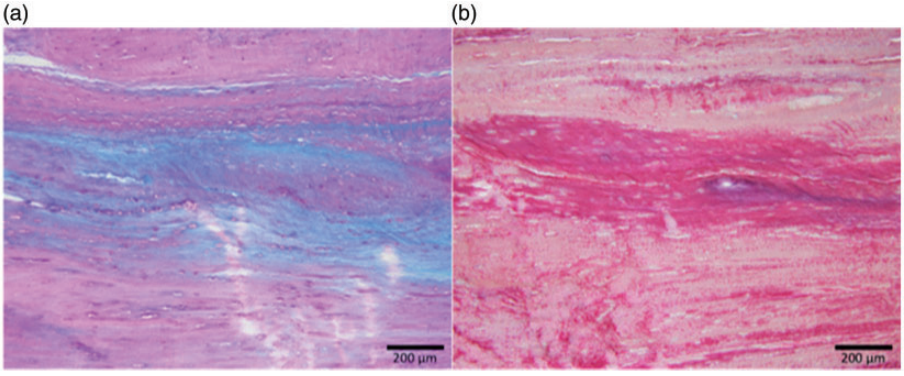

Figure 9. Histological slides of Case 2 show specimens of a part of the ligament stained by (a) Alcian blue/periodic acid-Schiff and (b) Elastica von Gieson. The pathological examination revealed mucoid degenerative tissue stained blue by Alcian blue, and this area had lost its normal fiber structure and was replaced by collagen fibers stained red by Elastica von Gieson.

Discussion

Kumar first reported mucoid degeneration of the cruciate ligament in 1999.[4] Although previously difficult to diagnose, mucoid degeneration can now be diagnosed by modern diagnostic modalities, especially MRI.[5] Mucoid degeneration of the cruciate ligament is a rare cause of knee pain without knee instability in middle-aged patients. According to previous reports, its incidence

is about 1.0%,[6] the average age at onset is in the fourth decade of life, and there are no sex-related differences.[7] However, recent reports have suggested that mucoid degeneration occurs pathologically in 26% of patients who have undergone TKA[7] and that ACL and PCL mucoid degeneration often occur together.[8] Therefore, it is likely that mucoid degeneration is more common than previously thought, and it may be overlooked in the clinical setting.

Mucoid degeneration is histologically characterized by an increase of mucoid ground substance in the connective tissue secondary to accumulation of dense granular material (glycosaminoglycans) between thin collagen fibrils. These pools of acid mucopolysaccharide are seen on Alcian blue staining and can accumulate within cysts.[4] Histologically, the mucoid ground substance has been demonstrated to be a mucoid extracellular matrix, which is composed mainly of proteoglycans and collagens; proteoglycans are composed of glycosaminoglycans covalently attached to specific core proteins.[9] Although the etiology of mucoid degeneration of ligaments is still unclear, mechanical stresses such as traction and impingement of the ligament are reportedly involved in this disease.[3,10–12] Bergin et al.[6] reported that such stresses are a precursor to complete rupture.[6]

The surgical treatment for symptomatic mucoid degeneration is generally arthroscopic partial resection of the ligament with longitudinal incision of the ligament along the fibrous direction,[13] and the clinical outcomes are reportedly favorable.[2] Some patients return to sports after this surgery, especially younger patients.[14] However, mucoid degeneration is associated with aging and OA; thus, anterior or posterior instability is a potential complication, especially in elderly patients. In previous studies, 7% of patients developed joint instability 2 to 5 years after partial resection that required ACL reconstruction,[15] and 10% of patients developed ACL tears after partial resection.[16] Some reports have suggested that ACL reconstruction should be performed in younger and more active patients following partial resection of the ligament.[13] Whether and when ACL reconstruction should be performed after partial ligament resection remain controversial. Further study is needed to define the criteria for treatment decisions regarding mucoid degeneration.

The tram-track appearance and celery stalk appearance are valuable MRI findings of mucoid degeneration of the cruciate ligament. These appearances can be seen throughout the entire ligament in most affected patients.[3] However, what each imaging finding indicates pathologically remains unclear. To verify the association between MRI findings and pathological findings, it is necessary to examine a specimen of the whole ligament. In the present report, the entire ligament with mucoid degeneration was successfully removed and evaluated pathologically in two patients requiring TKA. Pathologically, the central portion of the mucoid-degenerated lesion showed typical mucoid degeneration, whereas the marginal and bone-adherent portions showed no mucoid degeneration; this was consistent with the tram-track appearance on T2-weighted MRI. In addition, fibrous normal ligament tissues were observed in the longitudinal direction in the area of mucoid degeneration, consistent with the celery stalk appearance on T2-weighted MRI.

Both patients in this report had mucoid degeneration of the PCL and OA requiring TKA. High tibial osteotomy and unicompartmental knee arthroplasty are controversial surgical options for treatment of such patients. However, mucoid degeneration of the PCL is reportedly associated with degeneration of the ACL.[17,18] In addition, some authors have stated that retention of the PCL should not be recommended in the

treatment of severe OA because of architectural and functional damage to the PCL, including mucoid degeneration.[19,20] In fact, the pathological examination in our patients revealed that the mucoid degenerative ligaments had lost their normal fiber structure, which had been replaced by collagen fibers. Therefore, at our hospital, PS TKA is the first choice for patients with flexion contracture of $>10°$, FTA of $>185°$, and concern about the function of the PCL.

In Case 2, arthroscopic ACL resection had been previously performed for mucoid degeneration of the ACL, and the absence of the ligament may have contributed to the progression of secondary OA. Previous studies have shown that knee OA can induce ligamentous mucoid degeneration.[21,22] In contrast, mucoid degeneration of the ACL with OA is reported to be associated with progression of loss of the medial tibiofemoral joint space.[23] The number of patients with concurrent OA and mucoid degeneration of the cruciate ligament is expected to increase; therefore, these patients should be carefully observed because OA and mucoid degeneration require different treatment strategies, and both can progress.

In conclusion, in our two patients with mucoid degeneration, the entire PCL including its bony attachments was pathologically evaluated, and the relationship of the pathological findings with the MRI imaging findings was assessed. The pathological findings explained the tram-track appearance and celery stalk appearance on MRI and showed the absence of mucoid degeneration in the ligament attachment and marginal areas.

Availability of data and materials

The datasets of the present study are available from the corresponding author upon reasonable request.

Author contributions

RS and MN conceived and designed the study. RS, MN, KT, and KI wrote the paper. RS, YO, TO, and MN performed the surgery. SI determined the pathologic diagnosis. All authors edited and approved the manuscript prior to submission.

Ethics and consent for publication

Approval for the conduct and publication of this study, including all accompanying images, was obtained from the institutional review board (approval no. 5-16-55). Written informed consent was obtained from the patients for publication of this case report and accompanying images.

Declaration of conflict of interest

The authors declare that there is no conflict of interest.

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