Posttraumatic cartilage degradation progresses following anterior cruciate ligament reconstruction: A second-look arthroscopic evaluation

Abstract

Background**:** Several studies have demonstrated that posttraumatic knee osteoarthritis progresses even after anterior cruciate ligament reconstruction. Few reports described zone-specific cartilaginous damages after anterior cruciate ligament reconstruction. This study aimed to compare the status of articular cartilage at anterior cruciate ligament reconstruction with that at second-look arthroscopy.

Methods**:** This study included 20 patients (20 knees, 10 males and 10 females, mean age 22.4 years, Body mass index 24.4 kg/m^2) second-look arthroscopy. Mean periods from injury to reconstruction and from reconstruction to second-look arthroscopy were 3.4 and 15.3 months, respectively. Cartilage lesions were evaluated arthroscopically in the six articular surfaces and 40 articular subcompartments independently, and these features were graded with the International Cartilage Repair Society Articular cartilage injury classification; comparisons were made between the grades at reconstruction and at second-look arthroscopy. Furthermore, clinical outcomes were assessed at reconstruction and at second-look arthroscopy, using the Lysholm knee score, Tegner activity scale, International Knee Documentation Committee score, Knee injury and Osteoarthritis Outcome Score, side-to-side difference of the KT-2000 arthrometer, and pivot shift test.

Results**:** Each compartment showed a deteriorated condition at second-look arthroscopy compared with the pre-reconstruction period. A significant worsening of the articular cartilage was noted in all compartments except the lateral tibial plateau and was also observed in the central region of the medial femoral condyle and trochlea after reconstruction. However, each clinical outcome was significantly improved postoperatively.

Conclusions**:** This study demonstrated that posttraumatic osteoarthritic changes in the patellofemoral and medial compartments progressed even in the early postoperative period, although good knee stability and clinical outcomes were obtained. Care is necessary regarding the progression of osteoarthritis and the appearance of knee symptoms in patients undergoing anterior cruciate ligament reconstruction.

Introduction

Anterior cruciate ligament (ACL) injuries lead to posttraumatic knee osteoarthritis by inducing abnormal kinematics of the knee. ACL reconstruction (ACLR) can reduce excessive mechanical stress on articular cartilage and meniscus by restoring knee stability. However, several studies demonstrate that posttraumatic knee osteoarthritis progresses even after ACLR [1, 2]. Secondary prevention strategies to delay osteoarthritis onset after an injury are essential. Unlike established radiographic osteoarthritis, the trajectory of the early pre-radiographic stages of the disease, such as posttraumatic changes to cartilage and bone marrow, can be modified [3].

Recently, magnetic resonance imaging (MRI) techniques have proven useful in detecting early structural changes in all joint tissues. MRI studies revealed progressive degeneration in the patellofemoral (PF) or medial tibiofemoral (TF) cartilage in ACL-reconstructed knees about 2 years after reconstruction, which may be related with longer-term radiographic osteoarthritis [4, 5].

However, radiographically invisible pathologies such as cartilage defects and meniscal tears can also be visualized by arthroscopy. Arthroscopy, with its tactile and dynamic capabilities, permits the palpation of joint tissues with a probe, allowing the detection of degenerative change. Few reports have been published about early cartilage change after ACLR using arthroscopy [6]. Hence, the purpose of this study was to evaluate the site-specific changes in cartilage status after double-bundle ACLR using arthroscopy. We hypothesized that degenerative change would progress in specific subcompartments in the PF or medial TF cartilage early after ACLR via arthroscopy.

Materials and Methods

This study was approved by our Institutional Review Board and written informed consent was obtained from all included patients. From 2014 to 2017, 68 knees that underwent a double-bundle ACLR were examined. Six patients who had not yet undergone second-look arthroscopy and a patient who underwent revision surgery were excluded from the study. We also excluded 41 patients with a meniscal injury at reconstruction because meniscal injury is one of the major osteoarthritis risk factors. Overall, 20 knees (20 patients) were enrolled in this study. The variety of sports patients did included basketball in case of 7 knees, football in 4 knees, badminton in 3 knees and 2 knees each in fighting sports, skiing and volleyball in 2 knees. 17 knees had the bone bruise at preoperative MRI. The area of the bone bruise was recognized at lateral femoral condyle (LFC) compartments in 11 knees, lateral tibial plateau (LTP) in 2 knees, LFC and LTP in 2 knees and LFC and medial femoral condyle (MFC) in 2 knees. There were no cases of multiple ligament injury. Patient demographics are shown in Table 1.

Surgical technique

Double-bundle arthroscopic ACLRs were performed, using hamstring-tendon autografts for all patients [7, 8]. The femoral and tibial bone tunnels were created using an outside-in technique within the ACL footprints as previously described [9-11]. The mean diameter of the anteromedial (AM) bundle was 5.7 mm (range 5.0 – 6.0 mm) and of the mean posterolateral (PL) bundle was 4.9 mm (range 4.5 – 5.0 mm). The mean length of the femoral tunnel for the AM bundle was 38.6 mm (range 30 – 49 mm) and for the PL bundle was 37.3 mm (range 28 – 44 mm). Femoral fixation was achieved using the Tight Rope RT (Arthrex, Naples, FL, USA) or Endobutton system (Smith & Nephew Inc., Andover, MA) [12-14]. Tibial fixation was performed with the knee flexed at 20° using double-spike plates (Meira, Aichi, Japan), with an initial tension of 20 N for the PL bundle and 30 N for the AM bundle [10, 15]. The tension in each bundle was independently measured using a tensiometer.

We used the surgical option for cartilage damage separately. Either debridement or the untreated option was selected for the relatively mild cartilage damages like ICRS (International Cartilage Repair Society) grade 1 to 3 [16]. And bone marrow stimulation such as microfracture or drilling was used for severe cartilage damages like in the case of ICRS grade 4.

Postoperative rehabilitation protocols

All patients wore a knee brace for 1 week to promote initial healing of the graft, fixation points, and affected soft tissue. Knee range of motion exercises and partial weight bearing were initiated in the postoperative week 2. Full weight bearing was permitted at 1 month, running at 5 months, and a return to sports at 8 months postoperatively [9, 17, 18].

Evaluation of clinical and radiological outcomes

During the follow-up examinations, the Lysholm score, Tegner activity scale, Knee injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC) knee examination form, side-to-side difference of KT-2000 and pivot shift test were obtained as the clinical outcomes. Kellgren-Lawrence (KL) grade was also evaluated independently as the radiological outcome by two orthopedic surgeons blinded to the procedures. All measurements were compared between reconstruction and second-look arthroscopy.

Evaluation of cartilage injury

Cartilage injury was independently evaluated via arthroscopy in the six compartments comprising the patella, trochlea, medial and lateral femoral condyle (MFC and LFC, respectively), and medial and lateral tibial plateau (MTP and LTP, respectively) (Figure 1a). The patella, MFC, and LFC were each subdivided into nine subcompartments, MTP and LTP were each subdivided into 5 subcompartments, and the trochlea was subdivided into 3 subcompartments. Chondral injury at reconstruction and at second-look arthroscopy was compared in the 40 subcompartments (Figure 1b). Each subcompartment was evaluated according to the modified International Cartilage Repair Society's articular cartilage injury classification which combined the subclassification in each grade together and used as the point-addition scoring system. The same score, as evaluated in the ICRS grade, was given to the subcompartment. Each compartment score was calculated as the sum of all subcompartment scores belonging to the compartment for semi-quantitative evaluation. Two orthopedic surgeons independently evaluated the cartilage status at reconstruction and at second-look arthroscopy. Every assessment was performed using video arthroscopy. Each observer performed each evaluation twice, at least 2 weeks apart.

Statistical analysis

Statistical analysis was performed using EZR (Saitama Medical Center Jichi Medical University, Saitama, Japan). A paired t-test was used to compare pre- and postoperative data of the Lysholm score, IKDC knee examination score, KOOS, and side-to-side difference of KT-2000. Wilcoxon's signed-rank test was used to compare the subcompartment score, compartment score, and Tegner activity scale between reconstruction and second-look arthroscopy. Statistical significance was set as $p < 0.05$. The inter-observer and intra-observer reliabilities were assessed with the intraclass correlation coefficient (ICC), with ICC > 0.83 considered reliable measurement.

Results

Clinical and radiographic outcomes

The average Lysholm score, average IKDC score, average KOOS, median Tegner activity scale, average side-to-side difference of KT-2000 and positive pivot shift test were all significantly improved at second-look arthroscopy (reconstruction vs. second-look arthroscopy: 84.8 vs 97.4, 63.4 vs 89.0, 81.6 vs 94.4, 4 vs 6, and 3.5 mm vs 0.1 mm, 20 vs 0 respectively). Eighteen knees had KL grade 0 and 2 knees had KL grade 1 both at reconstruction and at second-look arthroscopy (Table 2). No knees had meniscal injuries at second-look arthroscopy. Additionally, no cases required treatment for the cartilage at ACL reconstruction. At second-look arthroscopy, microfracture was performed for ICRS grade 4 cartilage damage at the T2 subcompartment in one case. No cases needed special treatment for the cartilage at second-look arthroscopy.

Cartilage grade of each compartment

The inter-observer and intra-observer reliabilities were considered high, with mean ICC values of 0.92 and 0.94, respectively. The score of each compartment is shown in Table 3. Each compartment showed a deteriorated condition at second-look arthroscopy compared with the pre-reconstruction state. Significant worsening was noted in the patella, trochlea, MFC, MTP, and LFC compartments (p=0.019, 0.019, 0.005, 0.048, and 0.022, respectively).

Cartilage grade of each subcompartment

The score of each subcompartment is shown in Figure 2. 13 knees (65%) and 45 subcompartments (5.6%) had cartilage injury at reconstruction. 18 knees (90%) and 134 subcompartments (16.8%) had similar conditions at second-look arthroscopy. ~~17 knees and~~ Additionally, 111 (12.5%) of all 800 subcompartments became worse after reconstruction. Moreover, 669 (83.6%) of the remaining 689 subcompartments were unchanged and 20 (1.3%) improved. Cartilage injury significantly worsened in the MFC 5 and T 2 subcompartments, but no significant worsening was noted in other subcompartments. The worsened knee count in each subcompartment is described in the Figure 3a. The improved knee count in each subcompartment is described in Figure 3b.

Contributing factors of the specific subcompartments

We divided 20 knees into two groups; one was composed of the knees in which cartilage status got worse in T 2 or MFC 5 (n = 8) and the other was composed of the rest (n = 12). We evaluated the contributing factors of cartilage degeneration in the T 2 and MFC 5 subcompartments, which included gender, age, height, weight, body mass index, time from injury to the reconstruction, medial and lateral compartment bone bruise in preoperative MRI, postoperative side-to-side difference of KT-2000 and no cartilage injury at reconstruction. No other contributing factor were identified between the two groups (p value = 1, 0.245, 0.451, 0.426, 0.543, 0.761, 0.761, 0.443, 0.085).

Discussion

The most important finding of the present study was a significant worsening in the MFC 5 and T 2 subcompartments and in all the compartments except the LTP, despite good knee stability and clinical outcomes at second-look arthroscopy.

There have been some reports about the location of posttraumatic osteoarthritis after ACLR. Some radiographic reports have shown that posttraumatic osteoarthritis occurred at the PF and medial TF joints with long-term follow-up [19, 20]. Standard MRI techniques have proven more useful and more precise than radiographic techniques in detecting early degenerative cartilage change associated with cartilage injury. Su et al. quantified longitudinal changes in cartilage morphology and matrix in ACL-injured knees 2 years after ACLR using quantitative MRI. Their findings showed that significant progression of early degenerative change had occurred at the central aspect of MFC [21]. Lee et al. evaluated the changes in the site-specific cartilage status after a double-bundle ACLR using preoperative and follow-up MR images. They reported that the medial facet of the patella, anterior region of the lateral femur, and central region of the medial femur showed significantly more cartilage loss than the posterior and anterior regions of the medial tibia and the central and anterior regions of the lateral tibia 26 months after double-bundle ACLR [5]. These reports were consistent with our outcome which showed the significant increase of cartilage injury at MFC 5 subcompartment after ACLR. However, there are few reports about the progression of degenerative change after ACLR using arthroscopy. Asano et al. evaluated the articular cartilage lesion at reconstruction and at second-look arthroscopy to clarify the change in articular cartilage. A significant worsening was observed in all articular compartments except in LFC [6]. Previous reports have not discussed the reason for degenerative changes in specific subcompartments in detail.

Previous kinematic study of ACL-reconstructed knees has reported substantially altered tibiofemoral motion, resulting in a shift of cartilage compartments and in their contact with each other, and in the progression of early osteoarthritis [22]. Carpenter et al. described that, when knees were fully extended, the tibia in ACL-reconstructed knees were externally rotated by 3.6° ± 4.2° compared with the contralateral knees. They also showed that knee kinematic change was observed in the medial compartment [23]. Hoshino et al. reported that the mean joint sliding distance in the medial compartment was larger in reconstructed knees than in contralateral knees for anatomical double-bundle reconstruction [24]. In these reports, knee kinematic change was observed in the medial compartment and the tibia was externally rotated when the knees were fully extended, compared with the contralateral knee. This kinematic change might contribute to the progression of degenerative change in the medial compartment. There are few reports on the kinematics of the PF joint after ACL reconstruction. Tajima et al. reported that after single-bundle ACL reconstruction with a bone-patella tendon-bone autograft, the patella might tilt more laterally during flexion and tend to translate more laterally [25]. Additionally, they reported that the lateral facet peak pressure significantly increased at 90º of knee flexion in ACL-deficient knees. In vivo kinematic studies demonstrated that ACL deficiency causes increased valgus rotation and tilt of the patella, resulting in proximal and lateral shifts at the PF contact location [26]. Similar studies have reported that ACL deficiency results in significant increases in lateral patellar tilt and lateral patellar shift [27, 28]. The changes in the PF contact area and pressures in ACL-deficient knees and their possibility after ACL reconstruction might cause the development of posttraumatic PF osteoarthritis. We believe that the reason for progression of cartilage damage in PF joint is due to the temporary increase in mechanical stress to the PF joint because of the anterior instability being controlled drastically by the ACL reconstruction. Some factors as those mentioned above concerning kinematic change after ACL reconstruction might be related with our present results, which demonstrated cartilage degeneration at the MFC 5 and T 2 subcompartments. These worsening early osteoarthritis features on arthroscopy may reflect a progressive disease pathway that identifies those likely to experience future radiographic osteoarthritis and symptoms. Identifying patients with progressive early osteoarthritis features after natural biological graft healing and functional rehabilitation, but before established joint disease, may present opportunities to develop secondary prevention strategies. It is not clear why significant worsening was noted at the MFC 5 and T 2 subcompartments among all the subcompartments and at all the compartments except the LTP. We couldn't identify any contributing factors for cartilage degeneration in specific subcompartments. We think that the progression of cartilage damage couldn't be stopped completely after ACL reconstruction and the damage might become obvious about one year after reconstruction. Further investigations seem necessary to identify the exact cause of the posttraumatic osteoarthritis after double-bundle reconstruction.

Our study has several limitations that must be considered. First, a comparatively small sample size was investigated. Thus, further studies with more patients are needed. Second, the follow-up of this study was short because most patients returned for implant removal about 15 months after surgery. Thus, cartilage degeneration of the knee joint in the longer term is unclear. Third, the kinematic change in the knee joint was not examined in this study, which is thought to be the cause of the posttraumatic osteoarthritis after ACLR. Future investigation about postoperative kinematic change seems necessary.

Conclusion

We compared site-specific cartilage injury after double-bundle ACLR at reconstruction and at second-look arthroscopy. Significant worsening of the cartilage was observed at the central part of MFC and trochlea among all subcompartments and in all the compartments except the LTP, despite the achievement of good knee stability and clinical outcomes at second-look arthroscopy. Attention is required in the progression of osteoarthritis and the appearance of knee symptoms in those who undergo ACLR.

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Figure legends

Figure 1. Evaluation of cartilage lesions

a. Six compartments (P, patella; T, trochlea; MFC, medial femoral condyle; MTP, medial tibial plateau; LFC, lateral femoral condyle; LTP, lateral tibial plateau).

b. Forty subcompartments. Each compartment was divided into subcompartments.

Figure 2. Subcompartment scores

a. The sum of subcompartment scores at reconstruction.

b. The sum of subcompartment scores at second-look arthroscopy. * shows the subcompartments where significant worsening was found.

The number of cases with a cartilage lesion at ACL reconstruction is shown below the average values enclosed in parentheses.

Figure 3.

a. The knee count for worsening grade of cartilage injury in each subcompartment

b. The knee count for improving grade of cartilage injury in each subcompartment