Anterior cruciate ligament (ACL) tears are a common knee injury. In addition, medial meniscus (MM) injury occurs more frequently in ACL-deficient knees [1-3]. ACL reconstruction (ACLR) can restore the function of ACL-deficient knees with satisfactory clinical outcomes [4]. ACLR reduces the burden on the posterior portion of the MM [5]. However, ACL-reconstructed knees have a considerable risk of developing post-traumatic osteoarthritis (PTOA) of the knee during the long-term follow-up period [6]. Some studies have shown that ACLR did not reduce the incidence of early-onset knee osteoarthritis (OA) [7, 8]. In addition, the destruction of the ACL-lateral meniscus (LM) would worsen the OA of the knee [6]. This study assessed the occurrence of OA in knees with ACLR and the factors that influence the development of OA. We retrospectively evaluated patients who had undergone ACLR between January 2012 and December 2016. Clinical results were evaluated and compared between early and late follow-up evaluations. The results showed that ACLR reduced the progression of OA in knees with ACLR. Therefore, ACLR patients should be closely monitored for the development of OA following ACLR.
complex during the creation of tibial bone tunnels triggers LM extrusion and changes the position of the meniscus after ACLR, suggesting that ACLR itself could cause PTOA [9, 10]. It has been reported that articular cartilage degeneration is present in T1ρ after ACLR [11], and that longer post-surgical follow-up times were significantly positively associated with a higher proportion of PTOA development [12]. Thus, ACLR may not completely reduce secondary cartilage lesions after ACL tears.

Cartilage degradation and osteoarthritic changes after ACLR can be evaluated by magnetic resonance imaging (MRI) and/or radiography. Radiography is most commonly used to define knee OA and monitor disease progression; however, it is only sensitive to established joint disease [13, 14]. Some reports have suggested that early cartilage lesions can be detected by MRI [11, 15-17], but changes in the cartilage surface can be evaluated in further detail by arthroscopy.

We hypothesized that early cartilage lesions in the knee may develop over time after ACLR. The purpose of this study was to evaluate the prevalence of cartilage lesions after ACLR by second-look arthroscopy during the short-term follow-up period.

Materials and Methods

Patients. Thirty-seven patients who underwent anatomical double-bundle ACLR were examined. All of them underwent second-look arthroscopy at approximately 1 year after primary ACLR. Second-look arthroscopy was performed between March 2012 and December 2016. This study was approved by the Institutional Review Board of Okayama University Graduate School, and patients provided informed consent prior to participation.

We retrospectively reviewed the patients’ medical records to extract the age, sex, clinical findings, Lysholm score [18], and Tegnar score [19]. The side-to-side difference in the KT-2000 arthrometer measurement at 134 N was adopted as a parameter in the anteroposterior instability assessment at the time of ACLR and second-look arthroscopy. We evaluated articular cartilage and meniscus injury arthroscopically. Articular cartilage was assessed using the Outerbridge classification [20]. The Outerbridge classification consists of four grades. Grade 1 comprises softening and swelling of the cartilage. Grade 2 comprises fragmentation and fissuring in a region half an inch or less in diameter. Grade 3 is the same as grade 2, although the region involved is more than half an inch in diameter. In Grade 4, there is erosion of cartilage down to the bone [20].

Twenty-two male and 15 female knees were included in this study. The mean age was 22.5 ± 5.0 years (mean ± SD; range, 16-33 years) at primary ACLR and 24.2 ± 5.1 years (mean ± SD; range, 17-34 years) at second-look arthroscopy (Table 1). The mean time from injury to ACLR and from ACLR to second-look arthroscopy was 3.0 ± 2.1 (range, 1-10 months) months and 14.3 ± 4.4 months (range, 5-24 months). The patient demographics are summarized in Table 1.

The status of the cartilage and meniscus was assessed by second-look arthroscopy. This was performed in patients who wanted plates and screws removed. Plates, screw heads, and knots can induce pain in the lower leg in a specific sitting position with maximal knee flexion on the floor. At our hospital, patients who undergo ACLR usually request to have these implants removed rather than based on any recommendation by us [21].

Gender, age, the period from injury to ACLR, period from ACLR to second-look arthroscopy, and period from injury to second-look arthroscopy, and the presence or absence of meniscus injury were compared between the group with cartilage lesions and the group with intact cartilage at second-look arthroscopy.

Inclusion criteria. The inclusion criteria were as follows: (i) patients < 40 years of age at ACLR; (ii) patients who underwent anatomical double-bundle using the outside-in method; and (iii) patients who underwent ACLR within 1 year (patients who undergo ACLR ≥ 1 year after injury are at greater risk of secondary meniscus tears and arthritis [22], have a higher incidence of MM tears, especially bucket handle tears.

Table 1 Demographic data

| Male/Female (n) | 22/15 |
| Age (years) | |
| At ACLR | 22.5 ± 5.0 |
| At second-look arthroscopy | 24.2 ± 5.1 |
| Period (months) | |
| Between injury and ACLR | 3.0 ± 2.1 |
| Between ACLR and second-look arthroscopy | 14.3 ± 4.4 |
| Between injury to second-look arthroscopy | 17.4 ± 4.9 |

Anterior Cruciate Ligament Reconstruction (ACLR). Data are displayed as a mean ± standard deviation.
[23], and have a greater number of complications of chondral lesions, when compared with patients who undergo ACLR within 1 year of injury) [24].

**Surgical technique.** All knees underwent anatomic double-bundle ACLR with a hamstring tendon autograft (semitendinosus and semitendinosus/gracilis tendons). Graft fixation was achieved using an Endobutton or Endobutton CL (Smith & Nephew) on the femoral side. Graft fixation on the tibial side was performed using a Double Spike Plate and screw (Meria, Nagoya, Japan) [21, 25]. The femoral tunnel was created using an outside-in drilling system under the figure-of-nine leg position [26].

**Post-operative rehabilitation protocols.** All patients were placed in a knee brace for 1 week to promote initial healing of the graft, fixation points, and affected soft tissues. Knee range-of-motion exercises and partial weight bearing were initiated at post-operative week 2. Full weight bearing was permitted at 1 month post-operatively, and running at 5 months, with a return to sports permitted at 8 months [21, 25].

**Statistical analysis.** The measurements and clinical values at preoperative and post-operative examinations were assessed using the Wilcoxon signed-rank test. The comparison between the cartilage-lesion and intact-cartilage groups at second-look arthroscopy was assessed using the Mann-Whitney U-test. The comparison of meniscal injury between the cartilage-lesion group and intact-cartilage group was assessed using Fisher’s exact test. Data are presented as means ± standard deviations (SDs), and were deemed statistically significant if p < 0.05.

All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). More precisely, EZR is a modified version of the R commander that is designed to add the statistical functions frequently used in biostatistics [27].

**Results**

After ACLR, knee flexion improved from 132.0° ± 9.2 to 140.1° ± 6.6. KT-2000 side-to-side differences improved from 4.4 ± 2.0 mm to 1.2 ± 1.0 mm. The Lysholm score improved from 73.8 ± 13.5 to 95.6 ± 6.7. The Tegnar score improved from 6 ± 1.2 to 6 ± 1.0, which was the level before injury (median ± SD) (Table 2).

Cartilage lesions increased at second-look arthroscopy when compared with that at primary ACLR (Table 3). Most of them were Outerbridge classification grade 1 or 2. Representative arthroscopic findings are shown in Fig. 1. In this case, no cartilage lesion was noted at the time of ACLR, but during the second-look arthroscopy, we observed a cartilage lesion of Outerbridge classification Grade 2 at the lateral tibial plateau. Conversely, concomitant meniscus injuries decreased at second-look arthroscopy when compared with that at primary ACLR (Table 4). Thirteen and 15 knees with MM and LM injuries, respectively, observed at ACLR were repaired or underwent rasping. All knees were healed by the time of second-look arthroscopy except for 1 knee that underwent rasping after LM injury. In addition, MM injury was newly detected in 1 knee (Table 4). At second-look arthroscopy, 23 out of 37 knees exhibited cartilage lesions. The period from

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Post-operative clinical findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartilage lesion</td>
<td>At ACLR</td>
</tr>
<tr>
<td>Range of motion</td>
<td></td>
</tr>
<tr>
<td>Extension (°)</td>
<td>-3.0 ± 5.8</td>
</tr>
<tr>
<td>Flexion (°)</td>
<td>132.0 ± 9.2</td>
</tr>
<tr>
<td>Difference in KT-2000 arthrometer (mm)</td>
<td>4.4 ± 2.0</td>
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<tr>
<td>Lysholm score (points)</td>
<td>73.8 ± 13.5</td>
</tr>
<tr>
<td>Tegnar score (points)</td>
<td>6 ± 1.2</td>
</tr>
</tbody>
</table>

Anterior Cruciate Ligament Reconstruction (ACLR) Data are displayed as a mean ± standard deviation.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Arthroscopic evaluation of cartilage lesions at primary anterior cruciate ligament reconstruction and second-look arthroscopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartilage lesion</td>
<td>At primary ACLR</td>
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<tr>
<td>Patellofemoral</td>
<td>0/2/0/0</td>
</tr>
<tr>
<td>Medial Femoral Condyle</td>
<td>2/2/0/1</td>
</tr>
<tr>
<td>Lateral Femoral Condyle</td>
<td>0/1/0/0</td>
</tr>
<tr>
<td>Medial Tibial Plateau</td>
<td>0/2/0/0</td>
</tr>
<tr>
<td>Lateral Tibial Plateau</td>
<td>0/1/0/0</td>
</tr>
</tbody>
</table>

Anterior Cruciate Ligament Reconstruction (ACLR) The total number of cartilage lesion is shown as a/b/c/d.

- a: Outerbridge classification Grade 1
- b: Outerbridge classification Grade 2
- c: Outerbridge classification Grade 3
- d: Outerbridge classification Grade 4
injury to second-look arthroscopy was 458 ± 127 days and 383 ± 130 days, respectively, and the period from ACL reconstruction to second-look arthroscopy was 549 ± 134 days and 474 ± 163 days, respectively. The results showed that the period from injury to second-look arthroscopy and the period from ACLR to second-look arthroscopy in the cartilage-lesion group (n = 23) were significantly longer than in the intact-cartilage group (n = 14). However, the results showed no significant difference in the period from injury to ACLR between the cartilage-lesion and intact-cartilage group (Table 5).

![Fig. 1](image_url) Representative arthroscopic findings. (A) At the time of ACLR, no cartilage lesion was noted. (B) During the second-look arthroscopy, we observed cartilage lesion of Outerbridge classification Grade 2 at the lateral tibial plateau.

<table>
<thead>
<tr>
<th>Meniscal lesion</th>
<th>At primary ACLR</th>
<th>At second-look arthroscopy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MM</td>
<td>LM</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Repair</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Partial excision</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rasping</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

**Table 4** Arthroscopic evaluation of meniscal lesions at primary anterior cruciate ligament reconstruction and second-look arthroscopy

**Table 5** Comparison between cartilage-lesion and intact-cartilage groups at second-look arthroscopy

Anterior Cruciate Ligament Reconstruction (ACLR). Data are displayed as a mean ± standard deviation.

"Fisher’s exact test. "Mann-Whitney U test."
Discussion

The most important finding of this study was that, in some cases, articular cartilage lesions in the knee after ACL tears are not fully repaired by anatomical ACLR. These lesions can progress to detectable levels, as measured by arthroscopy, approximately 17 months after ACL injury. Clinical outcomes and KT-2000 side-to-side differences were improved, and meniscus injury was healed by the time of second-look arthroscopy. The period from injury to second-look arthroscopy and the period from ACLR to second-look arthroscopy was significantly longer in the cartilage-lesion group when compared with those in the intact-cartilage group. This is consistent with a previous study, which showed that the longer the post-operative course after ACLR, the higher the incidence of PTOA [12].

During ACLR in this study, MM and LM injuries were observed in 13 and 15 knees, respectively. A previous study reported that meniscectomy may cause progression of knee OA; [28] however, no patient underwent meniscectomy in this study. Conversely, 96% (27 out of 28 cases) of the MM and LM injuries observed at ACLR were healed by the time of the second-look arthroscopy (Table 4). This suggests that the increase in articular cartilage lesions at second-look arthroscopy was not due to the presence or absence of meniscus injury during ACLR.

If the period from injury to ACLR is long, the risk of developing a cartilage lesion may be high. However, in the case where the period from injury to ACLR was the longest at 290 days, no cartilage lesion was noted during either ACLR or second-look arthroscopy.

Upon evaluation of cartilage lesions after ACLR by MRI, studies have found that the T1ρ value on MRI of some cartilage compartments increase during the first year after surgery. The authors suggested that these cartilage lesions are associated with progressive degenerative cartilage changes during the early phase after ACLR [11]. Another study showed that high rates of degenerative change occur in the first 5 years after ACLR using MRI-based assessments [29]. Our results are consistent with those MRI evaluations. It has been suggested that cartilage lesions that are not evident at primary ACLR may gradually develop over time [11,29]. In the 14 cases showing no cartilage lesions at second-look arthroscopy, it is still possible that cartilage lesions will appear over time; obviously, this could not be explored in this study. At our hospital, second-look arthroscopy is performed about 1 year after surgery to assess the relative early symptoms of lesions. However, examination of the relationship between future progression of knee OA and the presence or absence of cartilage injury at second-look arthroscopy requires long-term follow-up, including X-ray and MRI assessments. No patient in the cartilage-lesion group in this study showed obvious symptoms related to cartilage injury. As shown in Table 3, there were 2 cases of Outerbridge grade 3 or 4, but in both cases, there were also no symptoms noted at second-look arthroscopy. Cartilage lesions were not revealed by MRI assessment just before second-look arthroscopy. However, it will be important to further elucidate the causal relationship between cartilage injury at second-look arthroscopy and future progression of knee OA to aid with treatment decisions.

A key factor in the development of PTOA after ACLR is the surgical procedure. Postoperative knee instability due to graft shifts in the bone tunnel or inadequate pre-tensioning [30,31], and changes in the meniscus position have been reported as likely causes [21,32,33]. Considering these factors during ACLR may lead to recovery of knee joint stability and reduce the risk of PTOA.

Limitations. This was a retrospective comparative study with a small sample size and short-term clinical outcomes. It was possible to capture the trend because we included patients who underwent anatomical double-bundle ACLR with the same procedures only in this study. However, generalizing the results of this study would be difficult because surgical procedures differ from institution to institution.

In conclusion, the results of this study suggest that, in some cases, articular cartilage lesions in the knee after ACL tears are not fully repaired by anatomical ACLR and can progress to detectable levels, as measured by arthroscopy, approximately 17 months after ACL injury. In ACLR, consideration of the risk of knee joint instability and clinical outcomes, and also follow-up assessments of the risk of PTOA due to articular cartilage lesion development over time are required.

Acknowledgments. We are grateful to Prof. Nobuhiro Abe, Drs. Shinichi Miyazawa, Takaaki Tanaka, Masataka Fujii, Hiroto Inoue, and Tomohito Hino for their cooperation.
References


