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MRI Observations of Patellar Tendon Length Change after ACL Reconstruction with Hamstring Autografts

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Summary: The post-operative patellar tendon length was studied to evaluate the possible tendon length change after anterior cruciate ligament (ACL) reconstruction with hamstring autografts. The Insall-Salvati index, modified Insall-Salvati index, curved modified Insall-Salvati index and Caton-Deschamps index were observed by MRI during a follow-up period of 12 weeks on 20 ACL reconstructed knees. The results showed no patellar baja or alta pre-existed on those ACL injured patients. After a follow-up period of 12 weeks, no patellar tendon length change was observed. It is suggested that the change of patella was not the primary reason that may contribute to the premature patellofemoral joint osteoarthritis after ACL reconstruction.
Key words: patellar tendon; hamstrings; anterior cruciate ligament reconstruction

Anterior cruciate ligament reconstruction (ACL-R) is a common procedure to re-establish knee stability and function. However, its effectiveness in preventing osteoarthritis (OA) is still controversial. Several studies have demonstrated a relatively high incidence of patellofemoral joint osteoarthritis (PFOA) after ACL-R[1–3]. While surgery aims to restore natural ACL anatomy, the best attempts at ACL-R continue to fall short of optimally restoring normal kinematics of the knee[4–6]. Comparing the anatomical and functional difference between healthy and surgically repaired knees may somehow explain the reason.

Patellar tendon (PT) takes a profound effect on the mechanics of the patellofemoral (PF) joint. Abnormal stress on PT can lead to overstress of PF joint, which contributes to the anterior knee pain (AKP) and degenerative change of PFOA[7]. Studies have reported that the length of PT (PTL) could be decreased after some surgeries on the knee, including proximal tibia fixation with open reduction and internal fixation, high tibial osteotomy and knee arthroplasty. Akkaya *et al* reported shortened PTL after ACL-R with bone-tendon-bone autografts[8]. However, there are few studies regarding PTL changes after ACL-R with hamstring autografts, a procedure that has no direct invasive maneuver on PT itself[9–12].

In this study, the post-operative PTL was studied to explore the possible relationship between PFOA and PTL change after ACL reconstruction with hamstring autografts. A sagittal MRI was chosen to measure the PTL because it provided a higher resolution for tendon tissue and a more accurate measurement on the patellar length (PL) and PTL than ordinary X-ray examination. Direct measurement of PTL can be criticized for not taking the size of the individual patient into account, so the measurement was standardized according to individual patellar bony landmark.

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1 MATERIALS AND METHODS

1.1 Patients

A continuous series of 20 knees from 20 patients [11 males and 9 females; mean age: 26.1 years old (15–40 years)] were subjected to ACL-R between 2003 and 2004. The Ethics Committees of Fukushima Medical University (Fukushima, Japan) approved the study protocol, and all patients signed the informed consent.

1.2 Operative Technique

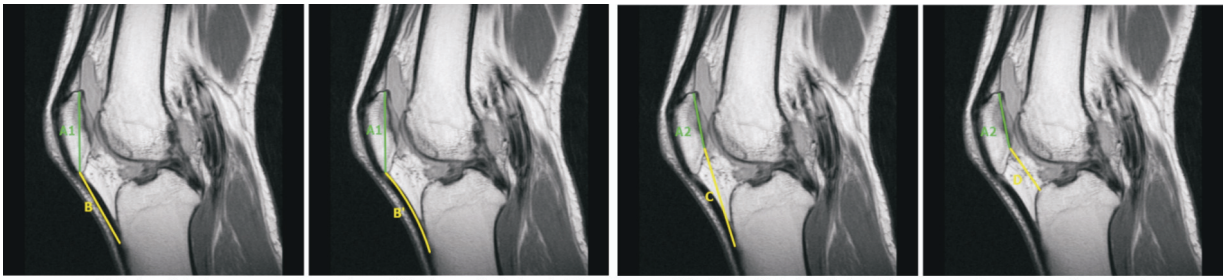
All the surgeries were performed by the same group of authors in Fukushima Medical University. An air tourniquet was placed around the thigh and inflated to a pressure of 250–300 mmHg after exsanguination. Gracilis and semitendinosus from the ipsilateral side were harvested as autografts, and single bundle ACL-R was performed. The femoral tunnel was prepared by trans-tibial tunnel procedure, and grafts were fixed by TRANSFIX and INTRAFIX© fastener (DepuyMitek, USA). The same postoperative rehabilitation program was introduced to all the patients.

1.3 MRI Investigation

All the 20 patients accepted MRI scan every two weeks after surgery, until 12 weeks. MR images of the ACL reconstructed knees on a 1.5 Tesla MR scanner (General Electric Healthcare, USA) were obtained by a phase-array torso coil. The knees were flexed at about 30°. Sagittal T1-weighted spin echo (repetition time msec/echo time: 400–600/10–14 ms) or proton density-weighted fast–spin echo [2000–4000/30–40 (effective), echo train length=4] was obtained using an extremity coil, a 15 cm field of view, a matrix of 256×192, and a 4 mm slice thickness with 1 mm interslice gap.

PL was measured from a single midsagittal image of the patella from the superior articular margin (excluding osteophytes) to the distal anterior tip. The midsagittal image of the patella was selected by determining the number of sagittal images in which the patella was visualized and divided in half. For example,

if the patella was visualized on 9 images, the measurements were performed on the fifth image. If the patella was shown on 8 images, the measurements were taken on the fourth and fifth images, and if the two measurements were different, the longer one was used for analysis. PTL measurement was obtained on the same sagittal image by measuring a straight line connecting between the patellar and tibial attachments along the inner margin of the tendon. The image of patellar tendon may not always be a straight line, but a rather curved morphological appearance as shown on some MR images. In such case, a linear length measure tool may not determine the real length of the tendon; curve length measurement tool was applied for a more objective data. For each patient, PTL was measured by linear length measurement tool and curve length measurement tool by AOC mini (version 1.3) software (Array Corporation, Japan). Every examiner measured the length of A1, A2, B, B', C and D, as shown in fig. 1, and the Insall-Salvati (IS) index, modified Insall-Salvati (MIS) index, curved modified Insall-Salvati (CMIS) index and Caton-Deschamps (CD) index were calculated for a standardized evaluation.



Insall-Salvati (IS) Curved modified Insall-Salvati (CMIS) Modified Insall-Salvati (MIS) Caton-Deschamps (CD)

Fig. 1 Methods for patellar tendon length measurement

Insall-Salvati, modified Insall-Salvati, curved modified Insall-Salvati and Caton-Deschamps indexes were studied for patellar tendon length evaluation. A1: patellar length, the greatest pole-to-pole length; B: patellar tendon length, the length of the posterior surface of the tendon from the lower pole of the patella to its insertion on the tibia; A2: length of the patellar articular surface; C: distance from the inferior margin of the patellar articular surface (as opposed to the lower pole of the patella itself) to the patellar tendon insertion; B': the curve length of PTL; D: distance between upper part of tibia and inferior part of patella

1.4 Statistical Analysis

IS index, MIS index, CMIS index and CD index were calculated by three individuals. Each examiner was blinded with regard to other examiner's data. An independent statistician performed statistical analysis. The mean value of three observers was used. Cluster analyses were evaluated by using the least significant difference (LSD) method. Comparisons within groups and between groups were performed using One-way ANOVA. SPSS Statistics (version 22) software was used for analysis. The results were considered significant at $P<0.05$.

2 RESULTS

The IS, MIS, CMIS and CD indexes were measured and calculated by three independent examiners. There were no statistically significant differences among three groups in the results from examiners above (fig. 2, $P>0.05$), which verified no inter-observer bias. There was a high intra-observer and inter-observer reliability for PL, PTL and curved PTL, which ranged between 0.94–0.98.

All of our patient's indexes were normal before the ACL-R surgery. No patellar baja or alta pre-existed on those ACL injured patients (fig. 3). However, many CMIS ratio in fig. 3 was higher than 1.2, which was considered upper limit of normal patella in IS ratio. That is because we used curve tool to measure the PTL, which was naturally longer than straight length measurement. And as a result, the CMIS ratio of every patient was higher than that of IS ratio.

The PTL might be changing with time after surgery. It was reported that highest amount of patellar shortening was observed between the fourth and the eighth postoperative week[13]. However, during the follow-up period of 12 weeks, the possible PTL change with time by IS, MIS, CMIS, CD indexes, and ANOVA study was carried out. There was no statistically significant difference in the PTL change with time by four measures (fig. 4).

3 DISCUSSION

Shortage over 10% of the PTL is considered as abnormal, and it can result in patella baja, which could lead to impingement of the patella on the tibia in full flexion and has been directly associated with movement restriction and AKP. The PTL has a profound effect on the mechanics of the PF joint. Patellofemoral contact force changes by 3% per millimeter of alteration in length of the tendon[14], and this elevated stress in patellofemoral joints was believed to lead to articular cartilage degeneration and subsequent AKP, and finally result in occurrence of PFOA.

Although many authors observed a relationship between PFOA and ACL-R[2, 15, 16], and previous studies reported patellar tendon shortening after bone-tendon-bone manner ACL-R, which has direct injury to the patellar tendon. The current study is the first, up to our knowledge, to prospectively evaluate the PTL change after ACL-R with hamstring graft. In this study, 20 ACL reconstructed knees were studied, and there was no significant PTL change before and after ACL-R. Therefore, our findings did not support a direct correlation between PTL change and PF joint degenerative process after ACL-R.

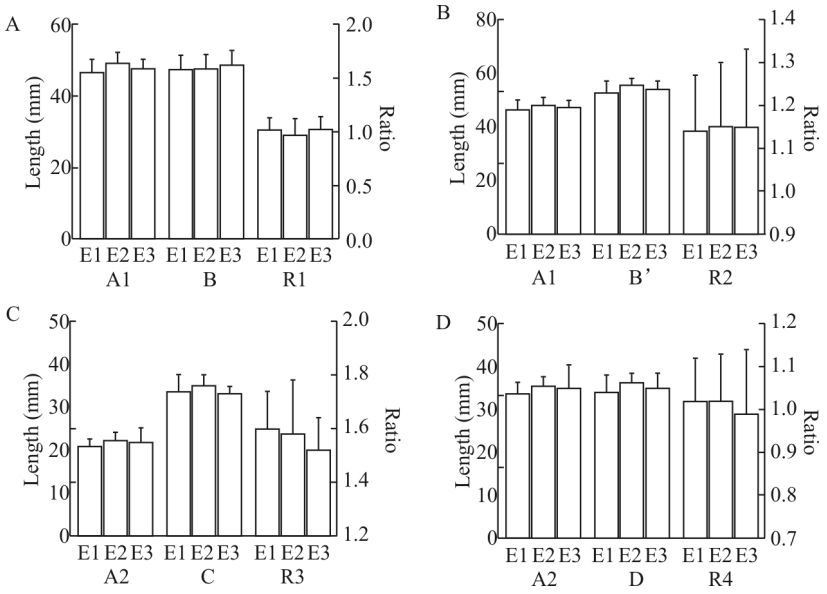


Fig. 2 Measurement results of IS (A), CMIS (B), MIS (C) and CD (D) indexes

A1: mean value of PL of all the patients by 3 examiners respectively (E1, E2, E3); A2: mean value of length of the patellar articular surface of all the patients by 3 examiners respectively (E1, E2, E3); B: mean value of PTL of all the patients by 3 examiners respectively (E1, E2, E3); B': mean value of curve length of PTL of all the patients by 3 examiners respectively (E1, E2, E3); C: mean value of distance from the inferior margin of the patellar articular surface of all the patients by 3 examiners respectively (E1, E2, E3); D: mean value of distance between upper part of tibia and inferior part of patella of all the patients by 3 examiners respectively (E1, E2, E3); R1: B/A1, IS index; R2: B'/A1, CMIS index; R3: C/A2, MIS index; R4: D/A2, CD index. There were no statistically significant differences among three groups in results from examiners, by One-Way ANOVA, which verified no inter-observer bias.

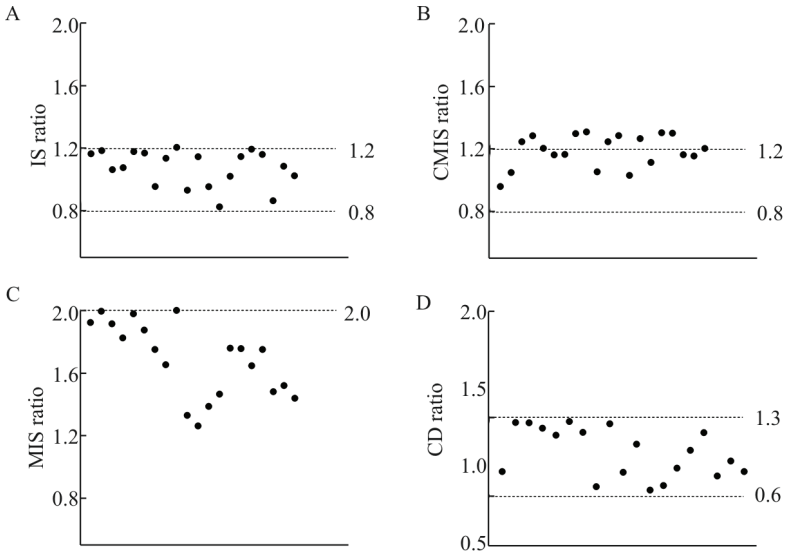


Fig. 3 Primary evaluation of patellar tendon abnormality for ACL injured patients

The IS (A), CMIS (B), MIS (C) and CD (D) indexes of 20 patients before surgery were normal. No patellar baja or alta pre-exists on the ACL injured patients.

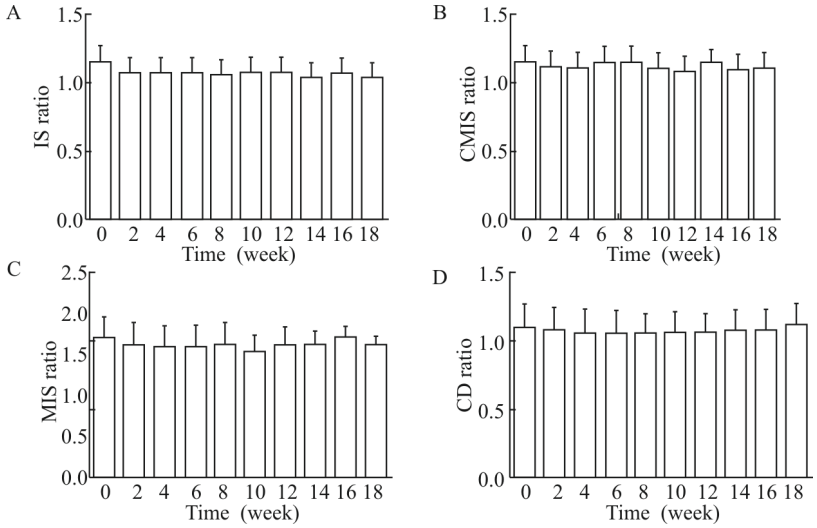


Fig. 4 The results of IS (A), CMIS (B), MIS (C) and CD (D) indexes every two weeks after reconstruction surgery
The number 0 on horizontal axis represents the day of surgery, and the number 2, 4, 6, etc. on horizontal axis refer to the number of weeks of check time post-operation. No statistically significant difference was observed with time.

The etiology of PTL shortening after surgery on the knee is unclear and multifactorial. Extrinsic factors may include scarring and contraction of peri-patellar soft tissues, ischemic contracture of the tendon, prolonged knee immobilization, and quadriceps weakness or inhibition secondary to pain or effusion. Intrinsic mechanisms of collagen contraction have also been proposed. No significant elongation and shortening were observed in our present research. Although ACL-R with arthroscopic skills is a routine popular procedure, there are still several special considerations: (1) Endoscopic portal establishment and surgical maneuver might cause directly heavy retraction of the edge of PT, which injuries the tendon mechanically; some authors favored an assistant trans-patellar tendon portal for a direct visualization of intercondylar notch area, which might injure the tendon directly. Trans-anteromedial portal reconstruction too close to the patellar tendon also might put heavy retraction on the tendon. For this technique, in order to get a satisfying femoral tunnel, heavy retraction was necessary for such intercondylar notch narrowing case. Therefore, intercondylar notch plasty is necessary not only for avoiding ligament impingement, but also for relieving the portal soft tissue tension. (2) During arthroscopic surgery, intra-articular visualization might be compromised by the interposition of the infrapatellar fat pad (IPFP) between the lens and notch. Especially when flexing the knee for femoral tunnel preparation, the IPFP might shield the visualization. In order to acquire an adequate view of the intercondylar-notch, shaving of the IPFP is frequently required, and over shaving might injure the blood supply to the PT by interrupting the infrapatellar anastomosis[17]. Moreover, recently a large number of studies had shown that IPFP, which regulates inflammatory cell recruitment and stem cell homing, was unregulated after ligament injury, so there may be a certain correlation between adipose-derived stem cells (ADSCs) from IPFP and injury tendon[5]. Injured PT repairing should include not only the self-repairing of the tendon, but also the biological repairing from ADSCs in IPFP. When both of the repairing failed to repair the damage of the tendon, PT may begin to shrink and scar, which will result in patella Baja. So, the IPFP should be carefully preserved as intact as possible. Using lateral higher arthroscopic portal, starting arthroscopy with the resection of the ligamentum mucosum and performing the tibial tunnel in 40°of knee flexion to optimize the intra-articular view without IPFP debridement was recommended[13]. (3) Different post-operative rehabilitation exercise protocol was among surgeons and physical therapists. Regular follow-up with appropriate pain control medicine prescription should be given to support an early painless rehabilitation process. (4) Some authors claimed artificial ligament graft over an autograft would provide benefits such as stronger strength, lack of harvest site pathology, easier surgical technique and shorter rehabilitation period.

There were still several flaws in our study. Firstly, the present study lacked of a long-term follow-up period. Our follow-up endpoint is only 12 weeks after the surgical reconstruction. However, Adam *et al* found that the highest amount of patellar shortening was observed between the fourth and the eighth postoperative week. No measurable change of the length of the PT was observed on the postoperative week 12[13]. Based on this rational, only a 12-week short-term following ACL-R follow-up was performed in this study; Secondly, different rehabilitation outcomes (range of motion) might correlate to the length change of PT. No functional evaluation was recorded in the follow-up. However, PTL might be one of the contributing factors of different rehabilitation outcomes and range of motion, not the primary causal factor. Thirdly, *in vivo* measurement of PF joint contact force and AKP were not included in our follow-up.

To sum up, as the etiology of OA following ACL-R is believed to be multifactorial, and morphological abnormality might explain the reason, no significant

decreases in PTL was observed after ACL-R with hamstring autografts in our study. Therefore, we believe change of PTL was not the primary reason contributing to the premature PFOA after ACL-R; there must be some other biomechanical factors (such as rotation stability control, cartilage adaption, etc[18–20]) or biochemical factors, altered in the knee joint after operation that might lead to the disturbance of the knee.

Conflict of Interest Statement

The author(s) declare that they have no competing interests.

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