ORIGINAL ARTICLE

The effectiveness of anterior cruciate ligament reconstruction on the patellofemoral stability and patellar height

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Abstract

Background: Considering the critical role the anterior cruciate ligament (ACL) plays in knee biomechanics, it is a logical hypothesis that ACL reconstruction (ACLR) will have positive effects on knee kinematics and stability. Our objective was to investigate radiologically and clinically the effect of single-bundle ACLR on patellar height and patellofemoral balance.

Methods: In this prospective study, 87 patients operated on with hamstring autograft-used single-bundle ACLR were analyzed. History of dislocation, stability-related physical examination findings, Tegner-Lysholm Knee Scoring Scale, and Kujala Anterior Knee Pain Scale were used for functional assessment. All patients underwent pre-and post-operative magnetic resonance imaging and Insall-Salvati (IS) Index, Caton Deschamps Index, Blackburne-Peel Index, and Patella-patellar tendon (P-PT) angles were measured on T1-weighted sagittal section images.

Results: A total of 79 patients (90.8%) achieved an excellent or good result, according to the Tegner-Lysholm Knee Scoring Scale, and the patients' postoperative 1st year mean Kujala Anterior Knee Pain Score was calculated as 90.4 (Range: 79.1 – 96.4). On physical examination, increased passive patellar translation was observed in 2 patients (2.3%), but the J sign appeared to be negative in all the patients. While all patellar height indices decreased after reconstruction, only the decrease in IS index was statistically significant (p=0.007). Moreover, the P-PT angle was found to be significantly lower after ACLR (p<0.001).

Conclusions: Our study is an essential step in demonstrating the relationship between anterior cruciate ligament reconstruction and patellar height. With single-bundle ACLR, sagittal balance improves, patellar height indices decrease, and patients' susceptibility to patellofemoral instability may reduce.

Keywords: Anterior Cruciate Ligament; Knee Joint; Patella; Patellar Ligament; Patellofemoral Joint.

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INTRODUCTION

While patellar height plays a crucial role in the extensor mechanism and contributes significantly to knee stability, patellar height disorders are associated with cartilage degeneration, instability, and deterioration in knee functions (1). More specifically, increased patellar height (patella alta) is associated with trochlear dysplasia and increased susceptibility to patellofemoral instability whereas decreased patellar height (patella baja) is associated with decreased range of motion and joint stiffness (2). The relationship between patellar height disorders and many knee-related clinical conditions such as total knee replacement, high tibial osteotomy, meniscal tear, and patellofemoral instability has been studied exclusively in the literature, considering their effects on clinical outcomes (3-5).

With an incidence of 25-78/100,000, the anterior cruciate ligament (ACL) rupture is one of the most common and most commonly treated knee injuries in the younger population (6,7). Furthermore, considering the critical role the ACL plays in knee biomechanics, it is inevitable that ACL reconstruction will have positive effects on knee kinematics, stability, and related pathologies (8,9). Although the relationship between ACL reconstructions and many different conditions such as meniscal tears, cartilage degeneration, and trochlear dysplasia has been investigated in the literature, the relationship between ACL reconstruction and patellar height disorders has been studied only in a limited number of studies, to the best of our knowledge (10-13). On the other hand, considering the important role of the anterior cruciate ligament in the balance of the knee and the effects of autografts used in ACL reconstruction on patellar or quadriceps tendon lengths, it is a reasonable hypothesis that there is a relationship between ACL reconstruction and patellar height (14,15).

The specific purpose of this study was to investigate radiologically and clinically the effect of ACL reconstruction on patellar height, knee stability, and patellofemoral balance by comparing the pre-and postoperative patellar height and analyzing post-operative knee functions of patients who underwent single-bundle ACL reconstruction using hamstring autograft. We hypothesize that knee stability will change positively in patients who have undergone ACL reconstruction, and the susceptibility to patellar height disorders will reduce.

MATERIALS AND METHODS

Following the ethics committee approval, patients who underwent single-bundle ACL reconstruction using hamstring autograft in our clinic between 2019-2022 were followed-up prospectively. To examine the effect of ACL reconstruction on patellar height, only isolated ACL ruptures were included in the study, while patients with medial and/or lateral meniscal tears were excluded. In addition, patients with known patellofemoral instability or a history of patella dislocation, patients who were treated with allograft or other autografts (bone-patellar tendon or quadriceps), patients who were operated via double-bundle technique, patients who did not comply with the recommended rehabilitation process, and patients who refused to participate in the study were also excluded. According to the inclusion and exclusion criteria, 22 patients were excluded and 87 prospectively followed-up patients were included in the study. Informed consent was obtained from all the patients. This study was approved by the clinical research Ethics Committee of the Ankara City Training and Research Hospital (Date: 17.03.2021, Number: E1-21-1636).

After a clinical diagnosis of ACL rupture with anterior drawer, Lachman and pivot shift tests, and radiological diagnosis through the examination of magnetic resonance imaging (MRI) images by orthopedic surgeons (ÖD and BG), single-bundle anatomical ACL reconstruction was performed using a quadrupled graft of semitendinosus and gracilis tendons (each doubled) as described in the literature (6,7). While endobutton-continuous loop was used for femoral fixation of the graft, bioabsorbable interference screws and staples were used for tibial fixation. All surgeries were performed by the same surgeon (ÖD). After the surgery, all the patients started closed chain exercises and weight-bearing as tolerated while open-chain exercises started at the postoperative 6th week. The same rehabilitation program was recommended and applied to all the patients in the same rehabilitation center, between the postoperative 6th week and 3rd month. Return to sports was not approved for any of the patients before six months. Following the rehabilitation process, MRI was performed, and functional measurements were made for all the patients during their first-year follow-up.

Tegner-Lysholm Knee Scoring Scale and Kujala Anterior Knee Pain Scale were used to evaluate the postoperative functional results of the patients (16). While evaluating the Tegner-Lysholm Knee Scoring Scale, the result was accepted

as "excellent" if the patient scored 90 points and above, "good" if the score was between 84-90 points, "fair" if the score was between 65-83 points, and "poor" if the patient was scored below 65 points, as described in the literature (15). While evaluating the Kujala Anterior Knee Pain Scale, patients were asked 13 questions according to the Turkish validated version (16) and scored between 0 to 100, in which higher scores were associated with better patellofemoral function and knee stability (3,19-22). Apart from these two scorings, in order to evaluate patellar stability and patellofemoral balance in all patients in their postoperative 1st year outpatient clinic controls, patients were questioned whether they had any patellar dislocations in the last year, whether they experience anterior knee pain, and whether they have increased passive patellar translation or positive J sign associated with patella alta in physical examination (23). In addition to the functional evaluation, patients' age, gender, side, trauma mechanisms, and complications were recorded. All functional clinical scoring and all physical examinations were performed by the same author (BG) at the same control (po 1st year) after patients started active exercise and adhered to a regular follow-up protocol.

To evaluate the change in patellar height before and after surgery, pre-and post-operative MRI images of all the patients, which were taken in a semi-flexed position, were examined. Although patellar height indices could also be evaluated with direct radiographs, to obtain images with similar qualities in the same flexion degree, all measurements were conducted in the first T1-weighted sagittal cross-section image where the patella is seen completely in MRIs taken at 30 degrees semiflexion. Insall-Salvati, Caton Deschamps, Blackburne-Peel indices, and patella-patellar tendon angle were measured pre-and post-operatively. All measurements were conducted by the same author, who is a radiologist with 10 years of experience (ISD) by using the software IC Measure® (The Imaging Source, Germany).

Insall-Salvati (IS) index is defined as the ratio of the length of the patellar tendon to the length of the patella. The length of the patellar tendon is the distance between the lower patellar pole and the tuberositas tibia whereas the length of the patella is the distance between the upper and lower patellar poles as shown in the figure (Figure 1). The normal range for IS index is between 0.8 and 1.2; ratios lower than 0.8 are described as patella baja whereas ratios higher than 1.2 are described as patella alta (24,25). Caton Deschamps (CD) index is delineated as the ratio

of the distance between the inferior edge of the patellar cartilage and the anterosuperior point of the tibial plateau to the length of the cartilage-covered articular surface of the patella (Figure 1). The normal range for the CD index is between 0.6 and 1.3; ratios lower than 0.6 are described as patella baja whereas ratios higher than 1.3 are described as patella alta (24,25). Blackburne-Peel (BP) index is defined as the ratio of the perpendicular distance between the inferior edge of the patellar articular cartilage to the articular surface of the tibial plateau and the length of the cartilage-covered articular surface of the patella (Figure 2). The normal range for the BP index is between 0.5 and 1.0; ratios lower than 0.5 are described as patella baja whereas ratios higher than 1.0 are described as patella alta (24,25). Patella-patellar tendon angle (P-PT angle) is used to analyze the sagittal alignment of the knee (26,27). It is reported in the literature that the P-PT angle is used to evaluate the sagittal patellar tilt, patellar tendon pathologies, and sagittal plane patellofemoral alignment (26,27). Accordingly, the P-PT angle is defined as the angle between the line connecting the upper and lower patellar poles and the line drawn from the lower patellar pole to the tuberositas tibia (26,27) (Figure 3).

Figure 1. Sagittal section image of the T1-weighted magnetic resonance imaging of a 26 years-old male patient. Insall-Salvati index (LT/LP) is defined as the ratio of the length of the patellar tendon (LT) to the length of the patella (LP). Caton Deschamps index (PTG/PG) is defined as the ratio of the distance between the inferior edge of the patellar cartilage and the anterosuperior point of the tibial plateau (PTG) to the length of the cartilage-covered articular surface of the patella (PG).

Figure 2. Sagittal section image of the T1-weighted magnetic resonance imaging of a 26 years-old male patient. Blackburne-Peel index (PP/PG) is defined as the ratio of the perpendicular distance between the inferior edge of the patellar articular cartilage to the articular surface of the tibial plateau (PP) and the length of the cartilage-covered articular surface of the patella (PG).

Figure 3. Sagittal section image of the T1-weighted magnetic resonance imaging of a 26 years-old male patient. Patella-patellar tendon angle (P-PT angle) is defined as the angle between the line connecting the upper and lower patellar poles and the line drawn from the lower patellar pole to the tuberositas tibia.

Statistical analysis was performed through SPSS version 26.0. The conformity of data to normal distribution was determined by using visual (histogram, probability plots) and analytical methods (Kolmogorov-Smirnov test). Mean and standard deviation were used as descriptive statistics for normally distributed variables whereas median and interquartile range values were used for skewed distributed variables. Paired Samples T-Test was used to determine the difference between the means for normally distributed data sets, and the Wilcoxon Signed-Ranks test was used for data sets which do not comply with the normal distribution. While the Chi-square test was used to compare categorical data, Fischer's Exact Test was adopted in cases where the Chi-square assumption was not met. A p value below 0.05 was considered significant. With measurements of 87 patients, the power of the study was found to be 81.7% by using the G power® version 3.1.9.4.

RESULTS

With a mean age of 33.6 years (Range: 18 – 47 years), 75 patients (84.3%) were male and 12 patients (13.8%) were female. A total of 79 patients (90.8%) achieved an excellent or good result according to Tegner-Lysholm Knee Scoring Scale, and the patients' postoperative 1st year mean Kujala Anterior Knee Pain Score was calculated as 90.4 (Range: 79.1 – 96.4). In the first-year evaluation of the patients, while none of the patients had a patellar dislocation, 9 patients (10.3%) had anterior knee pain during the postoperative one-year follow-up. On physical examination, increased passive patellar translation was observed in 2 patients (2.3%), but the J sign appeared to be negative in all patients. Detailed distribution of demographic data is presented in Table 1.

Table 1. Demographic profile of the patients

		Number of Patients (N=87 patients*)	Rate (%)
Age (years)		33.6 years (Range: 18 – 47)	
Gender	Male	75	86.2%
	Female	12	13.8%
Side	Right	51	58.6%
	Left	36	41.4%
Injury Mechanism	Sports Injury	67	77%
	Vehicle Accident	4	4.6%
	Industrial Injury	16	18.4%
Patellar Instability-Related Findings	Patellar Dislocation	0	0
	Anterior Knee Pain	9	10.3%
	Increased Passive Patellar Translation	2	2.3%
	J Sign	0	0
Tegner-Lysholm Knee Score	Excellent	64	73.6%
	Good	15	17.2%
	Fair	6	6.9%
	Poor	2	2.3%
Kujala Anterior Knee Pain Scale		90.4 points (Range: 79.1 – 96.4)	

N: number of patients

While all patellar height indices decreased postoperatively, only the decrease in IS index was statistically significant (P=0.007). Moreover, the P-PT angle was found to be significantly lower after ACL reconstruction (P<0.001). Detailed analysis of patellar height indices before and after ACL reconstruction is shown in Table 2.

Table 2. Pre-operative and post-operative patellar height values of ACL-reconstructed patients, based on pre-and post-operative T1-weighted sagittal section MRI images

	Pre-operative Values	Postoperative Values	P
Insall-Salvati Index*	1.08 (IR: 0.19) Range: 0.78 – 1.57	1.02 (IR: 0.17) Range: 0.65 – 1.66	**0.007**
Caton Deschamps Index*	1.05 (IR: 0.17) Range: 0.79 – 1.34	1.02 (IR: 0.21) Range: 0.09 – 1.54	0.067
Blackburne-Peel Index†	0.89 (SD: 0.117) Range: 0.69 – 1.18	0.87 (SD: 0.139) Range: 0.59 – 1.26	0.073
Patella-Patellar Tendon Angle*	141.3 (IR: 5.6) Range: 132 – 151.5	138.2 (IR: 7.2) Range: 128.9 – 156.3	**<0.001**

P: statistical significance value; IR: interquartile range; SD: standard deviation.

*: Median, interquartile range and minimum – maximum values were used as descriptive statistics for skewed distributed variables.

†: Mean, standard deviation and minimum – maximum range were used as descriptive statistics for normally distributed variables.

No tunnel malposition and impingement were observed in any patients clinically and during radiological examinations of MRI images. In four patients (4.6%), there were complaints of hypoesthesia in the anterolateral area of the knee, related to the injury of the infrapatellar branch of the saphenous nerve. In two patients (2.3%), swelling and erythema were detected in the knee after surgery, and patients were diagnosed with a superficial infection. Both patients responded to systemic antibiotic therapy. None of the patients needed a second operation.

DISCUSSION

This study is one of the first studies investigating the relationship between single-bundle hamstring autograft-used ACL reconstruction and patellofemoral balance (10-15,28). The strength and most important finding of our study is the low incidence of patellofemoral problems in the one-year follow-up of patients after single-bundle ACL reconstruction using a hamstring autograft. Patellar dislocation and J sign positivity were not detected in any of the patients. The increased passive patellar translation was observed in only two patients (2.3%). Although statistically significant (P=0.007 and P<0.001) decreases were detected radiologically in the Insall-Salvati index and P-PT angle, these decreases did not lead to a clinically significant difference.

Patella alta, upward slippage of the patella, is an important risk factor for patellofemoral instability (1,2). Although it has been defined with different values in different patellar height indices, increased index values are generally interpreted as patella alta (24,25). In our study, we hypothesized that in patients who have undergone ACL reconstruction, a more stable knee would be obtained, thus the susceptibility to patellar height disorders would decrease. In other words, we hypothesized that patellar height index values would decrease significantly in patients who underwent ACL reconstruction. Indeed, when the sagittal section images of the pre-and post-operative MRIs of our patients who had single-bundle ACL reconstruction using hamstring autograft were examined, we found that all patellar height index values decreased and the Insall-Salvati index showed a significant decrease (P=0.007). Considering the association of patella alta with patellofemoral instability, our finding can be interpreted as indicating that ACL reconstruction reduces the susceptibility to patella alta and possibly-related patellofemoral instability. Although it is an assertive statement that patellofemoral instability will decrease with ACL reconstruction, with the increased stability of the knee and patellar height changes after reconstruction, we believe that the patellar height-related patellofemoral instability may decrease. Interpretation of our finding is supported by the literature. Hao *et al.* (29) reported that the thinness of the ACL increases the susceptibility to patellofemoral instability. Cai *et al.* (30) reported that ACL reconstruction reduces patellofemoral dysfunction.

On the other hand, the very low rate of the decrease in IS index (from 1.08 to 1.02) raises doubts about whether our finding, although statistically significant, will be clinically effective. Fortunately, clinically, the patients did not show any patellofemoral balance-related symptoms (positive J sign, history of dislocation) at one-year postoperative follow-up, and the Kujala Anterior Knee Pain Score associated with patellofemoral problems was calculated as 90.4 (range 79.1 – 96.4) in our study. These results show that patients do not experience patellofemoral balance problems clinically after ACL reconstruction and are not prone to problems related to patellar height. When we examine the reasons for this finding, the first point to be emphasized is that we should discuss whether our patellar height index values are the cause or the result. There is no consensus in the literature regarding the effectiveness of patellar height in the initial ACL rupture. Güven et al. (31) reported that the IS index was higher in patients with ACL rupture than in the healthy population. On the other hand, Gobbi et al. (32) stated that patellar height disorders were risky in terms of patellofemoral instability, but not in ACL tears. With larger studies comparing the patellar height index values of patients with ACL rupture and the normal population, the relationship between patellar height and ACL could be demonstrated clearly. Another important reason behind the decrease in patellar height index values after ACL reconstruction is that, as we mentioned before, the ACL plays a regulatory role in many key mechanisms of the knee. For this reason, it is an expected result to obtain a more stable knee with its reconstruction. Another point to be emphasized is that, although clinically supported, only one of the patellar height indices (IS) has a significant decrease in our study. This can be an important point of contention but, in this study, we did not aim to investigate the superiority of patellar height indices to each other, and IS index has been defined as more reliable than its alternatives in the literature (24). It should be noted that anatomical variations of the patella or the patellar joint surface may also affect all patellar height index measurements.

Strength and balance of the quadriceps and hamstring muscles play a critical role in both the occurrence and post-reconstruction rehabilitation of ACL ruptures. Ahmad et al. (33) emphasized the effectiveness of reducing quadriceps dominance and increasing hamstring muscle strength in the occurrence of ACL rupture in female athletes. Cai et

al. (12) reported that quadriceps muscle strength after ACL reconstruction was associated with postoperative functional outcomes of the patients. All patients included in our study underwent the same physical therapy protocol and went through the same rehabilitation process. In this way, we aimed to achieve similar muscle strength and better function. In our study, a total of 79 patients (90.8%) achieved an excellent or good result, according to Tegner-Lysholm Knee Scoring Scale. On the other hand, it should be kept in mind that quadriceps atrophy is not uncommon after ACL reconstruction, may continue after rehabilitation, is directly related to patellar height, and play a crucial role in maintaining the normal anatomical relationship of the patellofemoral joint (12,34). Although we aimed to achieve a standard muscle strength by applying the same rehabilitation process for to patients in our study, more comprehensive results can be obtained with studies in which quadriceps muscle strength is measured objectively and compared with patellar height index values.

In our study, we found a significant decrease in the P-PT angle postoperatively (P<0.001). The most important point to emphasize is, although statistically significant, how clinically effective a mere 3-degree decrease on average in the P-PT angle (from 141.3 to 138.2) can be. Studies conducted with the P-PT angle in the literature have shown that even 2-degree decreases in this angle value can be evaluated as clinically significant (26,27). The P-PT angle is used to interpret patellar sagittal balance, and higher P-PT angle values are often associated with patellar tendon strain, tendinopathy, and anterior knee pain (26,27,35). In the stabilized knee after ACL reconstruction, the decrease in the postoperative P-PT angle can be interpreted as a decrease in the loads on the anterior knee and patellar tendon. Indeed, only 9 (%10.3) of our patients reported anterior knee pain during their follow-ups. On the other hand, the biological causation of the relationship between ACL reconstruction and decrease of the P-PT angle is not clear, and this relationship can be clarified with cadaver and clinical studies. It should be noted that the exclusion of reconstructions using bone-patellar tendon autografts also affects this finding. It is also an important question whether this small decrease can be explained by the measurement error. In our study, it

is aimed to prevent measurement error by performing all radiological measurements by an experienced radiologist.

Our study has several limitations. First, although the changes in IS index and P-PT angles are statistically significant, the distribution of the data is skewed, and the postoperative ranges seem to be widened. In addition, the sample size may also affect these variables. Further clinical and biomechanical studies investigating the relationship between ACL reconstruction and patellar height may obtain more objective results. Secondly, only patellar height indices of the sagittal plane were examined. More comprehensive results can be obtained with studies in which trochlear dysplasia and axial instability indices are also investigated. Another important limitation is that, as we mentioned before, the quadriceps muscle strength is not measured and evaluated. In addition, the evaluation of functional measurements (Tegner-Lysholm Knee Scoring and Kujala Anterior Knee Pain Scales) only postoperatively and the inability to compare the scores before and after surgery can be considered as a limitation. Finally, the fact that all the reconstructions included in the study are single-bundle reconstructions using hamstring autografts is a limitation. Although we have achieved standardization in this way, the effectiveness of different graft types and surgical techniques on patellar height and associated patellofemoral instability can be searched with larger cohorts and randomized trials.

Our study is an essential step in demonstrating the relationship between anterior cruciate ligament reconstruction and patellar height. With single-bundle anterior cruciate ligament reconstruction using hamstring autograft, sagittal balance improves, patellar height indices decrease, and patients' susceptibility to patellofemoral instability may reduce.

Declarations

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