The Early Results of the Reconstruction of Chronic Anterior Cruciate Ligament Deficiency with Single Tunnel-Dual-Bundle Technique and Quadruple Hamstring Autograft

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Abstract: *Purpose:* Our study retrospectively evaluates the early results of the reconstruction of anterior cruciate ligament (ACL) defficiency by single tunnel–Dual bundle technique and quadruple autogenous hamstring tendon graft.

Methods: Fourteen female and 46 male patients whom with chronic instability due to ACL deficiency were included in this study. The injury mechanism was sports related injury in 45 patients and in 15 patients the injury were other causes. All of the patients were treated with Single tunnel–Dual band technique and quadruple autogenous hamstring semitendinosus (ST) and gracilis (G) tendon graft. The patients were clinically evaluated with Lachman test, pivot-shift test, anterior drawer test, Mc Murray test, Lysholm activity scale and International Knee Documentation Comittee (IKDC) Questionaire preoperatively and postoperatively and the data were recorded.

Results: The average follow-up was 34.08 months (45–26 months). Both of the menisci were intact in 22 of the patients (36.6%) and meniscal lesion were present in 38 (63.3%) patients. Two of the patients with medial meniscal lesion were sutured with meniscal repair system. Also micro-fracture was performed in 4 patients with grade 3 chondral lesion in medial femoral condyle. The preoperative mean IKDC scores of 38.3 points (range 28.7–63.9) raised to 78.1 points (range 54-98.9) postoperatively and the difference was statystically significant.

Conclusion: In light of the findings of our study and related literature we can comment that the mid-term results of the reconstruction of anterior cruciate ligament (ACL) defficiency by single tunnel–Dual band technique and quadruple autogeneus hamstring tendon graft with AperFix fixation system are stisfactory.

Keywords: Anterior cruciate ligament, reconstruction, autologous graft.

1. INTRODUCTION

Increase in sporting activities due to healthy lifestyle practices increases the number and diversity of injuries seen in these activities at the same time. The knee is the most exposed joint to injury during sporting activities and anterior cruciate ligament (ACL) is the most frequently injured structure after meniscus. Epidemiological studies show that the prevalence of such injuries is approximately 1/3000 [1, 2]. Injuries of ACL lead to serious and permanent dysfunctions due to its important function in knee-joint. Acute or chronic failure of ACL develops anterior instability. The functional instability, which is clinically diagnosed or noticed by patients in their daily activities, leads to degeneration over time in articular cartilage and meniscus [3-7]. ACL injuries should be treated properly in order to minimize these effects and enable patients to fully return their social and business facilities back. Increased arthroscopic experience with the advances in arthroscopy and radiology led to rapid development of diagnosis and treatment methods in ACL. Different techniques can be used in surgical reconstruction of ACL. Interference screws, cross pin system (TransFix; Arhrex, Inc., Naples, FL, USA) and endobutton (Endobutton Smith and Nephew Inc., Andover, MA, USA) system are widely used materials in the femoral fixation in ACL reconstruction and the most studied. New technologies and new studies are continually produced to advance in ACL surgery results.

In this retrospective study, with the hypothesis of double-bundle anterior cruciate ligament reconstruction using a single femoral and tibial tunnel can closely reproduce intact knee kinematics, the mid-term results of reconstructions that we have carried out in patients with ACL rupture with Aperfix a new method of fixation are evaluated and results are discussed with the results of other techniques in light of the literature.

2. PATIENTS AND METHODS

Sixty patients, who were diagnosed to have ACL deficiency and were reconstructed with quadruple hamstring autograft with Aperfiks technique in Orthopedics and Traumatology Department of Antalya Education and Research Hospital were included in our study. Inclusion criteria in the study was the patients

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whom admitted for regular control and whose postoperative twenty-forth month test results were recorded.

Preoperative and postoperative assessments of patients were made through physical examination and radiologic examinations. Clinically the patients were evaluated by Lachman test, pivot shift test, anterior drawer tests by physical examinations and the results of these tests were recorded. Also all patients were assessed for the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC) and Lysholm activity scales.

The same technique (Single Tunnel-Dual-Bundle Technique and Quadruple Hamstring Autograft) was used in all patients as the surgical technique. Patients underwent general or spinal anaesthesia. A tourniquet was applied to the extremity which would be operated, when patient was in supine position. The time period for tourniquet was less than 2 hours. All patients were given Cephalosporin of 1g for prophylaxis infection one hour before the operation. Examination of the knee was repeated under anesthesia in all patients before starting the operation. The standard anterolateral and anteromedial portals were used. Accompanying meniscal tears, cartilage injuries and synovial pathologies were diagnosed. Chondral injuries were treated by debridement, microfracture and shaving. Patients, who required doing so, femoral notchplasty was also added. Then, the process for graft retrieval was performed. First of all, patella, patellar tendon, joint lines, tibial tuberosity was marked with a sterile pen, and then, sartorius tendon was explored through a longitudinal incision and the underlying semitendinosus and gracilis tendons were released with blunt dissection and separated from the musculo-tendinous junction with the help of a tendon scraper by preserving the superficial medial collateral ligament and releasing them one by one subperiosteally. Following the graft preparation, the thickness and length were measured with measuring tubes. Grafts were folded out in half and prepared for reconstruction. The tibial tunnel was reamed through the anteromedial surface of the tibia at the level of the tibial tubercle, passing through the landmarks of the center of the ACL remnant. A Kirschner wire was inserted through the tibial tunnel, aimed at the 2- or 10-o'clock position and 7mm anterior from the posterior bony edge of the intercondylar wall of the femur. The femoral tunnel was reamed through the tibial tunnel with the knee flexed to 90° using a 4.5-mm– diameter drill (to the lateral cortex of the distal femur. A final 35-mm–long femoral socket was then created by a cannulated reamer that matched the prepared graft diameter (8-8.5mm).The tibial and femoral tunnels were opened using the guidance system and fixed properly and with the appropriate tension using the Aperfiks system (Ceyyene Medical, Scottsdale, Arizona) the way that the semitendinozus tendon to represent the anteromedial bundle (AM) and gracilis tendon the posterolateral bundle. The redundancy in sutures and tendons was cut out. The tendon portion of 2.5cm was sutured leaning on the tibial periosteum. The graft was checked again arthroscopically to see whether or not the graft was tightening in flexion and extension movements in the knee. The stability of the knee was controlled by Lachmann and anterior drawer tests. Portals were sutured by placing a hemovac drain into the knee through anterolateral portal after washing the inner knee. After medical dressing, the knee was Jones bandaged in full extension.

Ice was applied periodically and the drain was pulled out at twenty-fourth hour after the operation. Antero-posterior and lateral radiographs of the patients were taken. Except for two patients with meniscus repair and four patients with micro-fracture repair, loading on the knee was not limited. Quadriceps exercises were started immediately. Patients were instructed about their exercise programs and discharged from hospital at the 3rd day post-operatively. Patients were applied "Lock Knee Brace" on the operation site for six weeks and followed up by applying an effectively controlled rehabilitation program. The rehabilitation program consisted of 3 parts. From postoperative 1st day to the end of 2nd week patients were followed with a locked knee brace at 0 degrees when walking with crutches and supported with passive range of motion at 0-90 degrees in bed, active knee flexion at 0-90 degrees, isometric quadriceps exercises, elevation in bed. From 2nd week to 6th week isometric hamstring and hip exercises were added to first therapy regimen. After 6th week brace was discontinued and rapid walking exercises were started if the operated site has gained 70% power of the other quadriceps, guarded running after 3rd month and returning to sports activities after 5 months.

The average follow-up was 34.08 months and the longest follow-up was 45 months and the short follow-up 26 months. Patients were discharged at the 3rd day post-operatively and controlled in the 14th day, 1st month and then once a month till 3months. Patients with limitation of movement ability were started a

physical therapy program in the 4th week of the operation. After the 4th week, patients were recommended to go through examination every 3 months.

3. RESULTS

Of all the patients 14 patients were female (23.3%), 46 were male (76.7%), and 26 (43.3%) patients had right 34 (56.7%) patients had left knee injury. Complaints of the patients during applying to our clinic were summarized in Table **1**.

Table 1: Complaints of the Patients

	Number	Percent
Pain	36	60%
Swelling	4	6.6%
Lock	14	23.3%
Instability feeling	45	75%

ACL injury was caused by sports in a total of 45 (75%) patients and non-sports injuries in 15 (25%) patients. The time elapsed between the occurrence of ACL injury and date of operation varies from minimum 2 months and maximum 2 years, and the average time period was 7 months. Results of anterior drawer tests, pivot shift, Lachman and Mc Murray tests of the pre-operative physical examination are summarized in Table **2**.

Table 2: Clinical Examination Results

	Number	Percent
Anterior Drawer	60	100%
Pivot Shift	52	86.6%
Lachman	60	100%
Mc Murray	38	63.3%

While both meniscus were intact in 22 patients (36.6%), 38 (63.3%) patients had meniscal lesions. 24 of these lesions (40%) were in medial meniscus, 8 (13.3%) in lateral meniscus and 6 (10%) in medial and lateral meniscus. Two patients with medial meniscus rupture were repaired with the meniscus suture system and the remaining meniscal tears were treated with partial menisectomy arthroscopically. Four patients with grade-three chondral damage in the medial femoral condyle were treated with microfracture.

While preoperative average score of patients by subjective Lysholm scoring was calculated as 37.8±19.1 (range 15 to 62) and came to 84.3±8.1 (range 65 to 100) postoperatively. The results of Lysholm score were; excellent in 30 patients, good in 6 patients, moderate in 24 patients postoperatively. No poor result was found Table **3**.

Table 3: Lysholm Score Table by the Number of Patients

Lysholm Score	Post-Traumatic (Number of Patients)	During Final Examination (Number of Patients)
95-100 Excellent	0	30
84-94 Good	0	6
65-83 Moderate	14	24
64 and below Poor	46	0

Patients' IKDC scores were recorded preoperatively and at the final examinations. According to these results, 42 (70%) patients were in Group A (excellent) and B (good), 18 (30%) patients were in Group C (abnormal) and there was no patient in Group D (poor) Table **4**. While the averages of IKDC subjective knee scores of all the patients was 38.3±15.6 (range 28.7 to 63.9) preoperatively, this ratio increased to 78.1±16.9 (range 54 to 98.9) in the final examination. The pre-operative and post-operative difference is statistically significant ($p = 0.0001$) Table **5**.

Table 4: Number of Patients by IKDC Score Groups

IKDC Score	Number of Patients in Pre-Operative Score Group	Number of Patients in Post-Operative Score Group
A (normal)	0	26
B (near-normal)	0	16
C (abnormal)	12	18
D (poor)	48	0

None of patients had limitation in range of motion. In the assessment of femoral diameters, measured from 15cm proximal to the upper pole of the patella in 8 patients, 2cm and in 4 patients 3cm of muscular atrophy was detected.

Table 5: Pre-Operative and Post-Operative Values of the Patients' Scores Showing a Statistically Significant Difference

Variables	Pre-Operative X ± SD	Post-Operative X ± SD	p
Lysholm score	37.8±19.1	84.3±8.1	0.0001
IKDC Subjective Knee Score	38.3±15.6	78.1±16.9	0.0001

The pre-operative Lachman test were evaluated as + in 4 patients, + + in 44 patients, + + + in 12 patients, were recorded as + + in 2 patients, + in 24 patients and negative in 34 patients post-operatively.

One of the patients admitted to the emergency department with the complaints of tenderness, pain and fever increase in the calf in the post-operative 4th day after discharge. This patient was diagnosed to have deep vein thrombosis after examination and was hospitalized in our clinic and treated. The patient's symptoms regressed after low molecular weight heparin treatment and was discharged in the 5th day of the hospitalization with a home treatment plan. In three patients, hypoesthesia was detected around the incision site. The infrapatellar branch of the saphenous nerve was considered to be injured due to the localization of the incision. This complaint did not affect patients' daily activities.

4. DISCUSSION

The most common lesion in knee injuries is ACL injury. The incidence in the general population is approximately one in three thousand according to McGinty [8]. The most common cause (70%) is sports injury. The injuries in 50% of the patients in our study were developed due to sports injury [9].

There is not any consensus fully reached on the upper age limit in ACL reconstruction, and determining the treatment taking daily activities, life expectancy, sport activities, degree of influence on daily activities of patients into account would be the appropriate approach [10].

In our study, the mean age was 28.8, and the minimum age was 16 and maximum age was 44. Gender was found to be the second important predisposing factor of anterior cruciate ligament injury [11]. The rate of anterior cruciate ligament injury in women, doing the same sport activity, is higher than the rate in men. There are several reasons for this situation. The intercondylar notch stenosis and ligament laxity are seen in women more than men, and the cross-sectional area of the anterior cruciate ligament is smaller. In addition, the most important factor is hormones. The estrogen hormone in women significantly supresses the fibroblast proliferation and procollagen synthesis [11]. In our study, 23 patients (76.6%) were male and 7 (23.3%) were female. The possible causes for this is that women in our country do sports less.

Diagnosis of ACL injury is established with anterior drawer, Lachman, pivot shift tests clinically. Magnetic resonance imaging techniques is used to detect accompanying meniscus and chondral lesions [12]. However, the sensitivity of magnetic resonance imaging in detecting the lateral meniscus lesions of acute ACL rupture is low [13]. Accompanying meniscal lesions are important in deciding surgical treatment. Approximately 50% of ACL injuries contain additional meniscus injury. In our study, this ratio was 63.3%.

Noyes argues that reconstruction in the acute period is not reasonable as it increases the risk of arthrofibrosis and causes limitation in movement ability [13]. However, Kurosaka argues that chondral lesions due to instability episodes will increase and chance of success of the treatment will decrease due to meniscus ruptures as the time period between injury and reconstruction lengthens out [14]. Today, the general trend in terms of timing of the surgical treatment is to achieve a good range of motion and leg control, complete quadriceps muscle strength and patellar mobility as soon as possible after anterior cruciate ligament injury, and carry out the reconstruction under these conditions [14-16]. In our cases, the time elapsed between injury and surgery was an average of 7 months.

Graft selection is one of the important issues discussed in ACL reconstruction. Efforts to find the ideal graft are still continuing [17]. Synthetic grafts are not currently used due to their adverse results [18]. Allografts are not used widely due to their disadvantages such as risk of infection, immune response, graft rejection, resorpsion in the tunnel, long re-modelling duration and high cost, although allografts do not pose any additional morbidity, shortens duration of operation and can be prepared at desired size and allows operation to be performed with a small incision or just an arthroscopic approach [19].

Grafts that are preferred more due to their adaptation in the joint and successful results in the graft ligamentization are biological grafts, namely autografts [20]. Many clinical trials have reported that single-bundle ACL reconstruction is more successful in terms of stability [21, 22]. However, development of a high number of osteoarthritis is in question in long-term follow-up results [23, 24]. A large number of clinical and biomechanical publications have recently reported that dual-bundle ACL reconstruction provides a knee joint stability at the normal intact ACL level compared to single-bundle ACL reconstruction [25-28]. In contrast, there also many studies reported that dual-bund ACL reconstruction does not have a significant advantage comparing to single-bundle ACL reconstruction [29-32]. Many different variables, such as tunnel positions used in single or dual-bundle ACL reconstruction technique, initial graft tension, differences in graft determination, assessment parameters used, can be the reasons for the controversial points in ACL reconstruction.

The concept of robust graft selection has gained importance in recent years together with the perception of rapid rehabilitation. Grafts to be selected must have the biomechanical properties suitable for rehabilitation. The graft used in all our patients is dual-bundle quadrupled hamstring (semitendinozus and gracilis) auto-graft. Optimal ACL reconstruction depends on many factors such as selection of graft strong enough, opening suitable bone tunnels, strong graft fixation and early graft-bone recovery. Determining the tibial and femoral tunnel positioning in the anterior cruciate ligament reconstruction is an important and difficult point [19]. The ideal tibial tunnel should be opened so that the graft will be prevented to jam in the intercondylar notch, the transtibial guide will be centred above after the tunnel is opened and the intra-articular exit point of the tunnel will not force the graft to tear due to insufficient length and angle. To find the ideal position of the tibial tunnel, numerous formulas were put forward, but among these formulas, the system, introduced by Jackson and Gasser, that is based on the selection of the anatomical points as a guide has been adopted the most. Anatomical guide points are the stump of the lateral meniscus anterior horn, medial tibial spur, posterior cruciate ligament and anterior cruciate ligament. Tibial tunnel must be opened so that the angle of the tibial plateau is 45-60°, averagely 55°, the posterior cruciate ligament is in front of the anterior edge about 5 to 7mm, the anterior cruciate ligament stump is centralized 1/2 in the posterior and shows continuity with the internal portion of anterior horn of the lateral meniscus [33]. In the event that the mid-point of the articular exit point of the tibial tunnel remains in front of or behind the tangential line drawn to tibia from the intercondylar notch roof intercondylar notch roof in sagittal plane, this situation affect the results of the reconstruction causing impingement of the graft in the notch [34]. Positioning of the tibial tunnel anteriorly of this line leads to limitation of extension in the postoperative period. Positioning in posterior will cause the graft to jam in the intercondylar notch in the extension. In both cases, graft failure occurs at the end of about five years, and instability repeats [14]. Yosmaoglu *et al*. reported that no statistically significant difference was found in their study that they compared the postoperative first year functional results of the Endobutton post-fixation method to the femoral post-fixation method using hamstring tendon graft [35].

Different techniques can be used in graft determination. Interference screws, cross pin system (TransFix; Arhrex, Inc., Naples, FL, USA) and endobutton (Endobutton Smith and Nephew Inc., Andover, MA, USA) system are widely used materials in the femoral fixation in ACL reconstruction and the most studied [36-40]. Ma *et al*. and Harrow *et al*. reported that femoral fixation from the far end of the tunnel provided a better tendon-bone union like the cross pin when the fixation with pin in the tunnel was compared to fixation with endobutton, and they attributed this situation to that the pin remained between the bone and tendon in fixation with pin [39, 41]. Brand *et al*. have emphasized that the most important drawback of the cross-pinning method is expansion of the tunnel due to the fixation remaining in the depth of the tunnel [36]. Hemanth *et al*. reported that reconstruction with AperFix method provided a more efficient and stability close to a robust cruciate ligament both in the anterior and posterior translation and rotational stability especially at low degrees of flexion (0-30') compared to the physiological parameters of the anterior cruciate ligament and they attributed this result to more efficient physiological tension of the anteromedial and posterolateral bundle at varying degrees of the knee flexion in a biomechanical study they conducted with the use of Endobutton post-fixation and single-tunnel dual bundle AperFix femoral implant with a single tunnel using hamstring tendons and robotic measuring device [42].

In our case series, we used the special guide system, a system used by authors like Cole, Ericsson, Woo, Miller and McGinty and allows tunnel opening on the basis of anatomical points. Currently, new fixation

systems are being developed because each of these systems has its some challenges and convenience in use. AperFiks fixation system, used in our study, was also such a system and facilitated the procedure. In our series the femoral tunnel was prepared by placing the guide in the pilot hole on the femoral condyle 6mm anterior to over the top spot in approximately the 11 o'clock position on the right knee or the 1 o'clock position on the left knee 40mm in depth with a diameter of 9-10 or 11mm depending the diameter of the graft. Interference screws, staple, post-fixation screws are the most commonly used materials in tibial fixation of the hamstring tendons. We have used the radiolucent interference screw of the AperFix system. A rigid fixation was made by compressing to the bone on the both sides in the tunnel with an interference screw placed between the two grafts following the rotation to create an anteromedial and posterolateral bundle before the fixation when the knee is 30 degrees of flexion and the graft under tension, and the intra-operative tension of the fixation was checked with examination. Taking the results during the control period into account, we thought that fixation with the Aperfiks system in the knee stability would be an effective method and it might have been a good alternative to other methods.

Post-operative rehabilation program is one of the most important steps of ACL reconstruction. Aim is to prevention of arthrofibrosis by controlling inflammation to facilitate full range of motion, maintaining graft fixation and early weight bearing. Patients were applied "Lock Knee Brace" on the operation site for six weeks and followed up by applying an effectively controlled rehabilitation program. According to the literature, the average time to return to active sports is 6 months post-operatively [17]. In our study, the average time to return to active sports (amateur) is 6.8 months. It is remarkable that this period is shorter in patients with a higher preoperative activity score and adapting to rehabilitation better.

In the study of Gobbi *et al*., IKDC scores of 80 patients after 36 months follow-up were found as follows; A-B in 72, C in 7 and D in 1. In our study, IKDC score of patients in the final examination was A and B in 70% (21 patients). 9 patients were in Group C, and there was no patient in Group D. This result is satisfactory when evaluated with short-term follow up and low pre-operative scores.

The aim in the surgical treatment of the anterior cruciate ligament deficiency is to provide anterior stability of the knee and enable patients to return their sports and daily activities by eliminating anterior episodes as well as preventing occurrence of additional pathologies. In order to prevent the development of post-operative arthrofibrosis, ACL surgery must be carried out as soon as possible after the inflammatory symptoms of the knee are recovered and a full range of motion is achieved in the knee.

Another factor as important as surgery in patients, who undergo ACL reconstruction, is rehabilitation programs. Accelerated rehabilitation should be preferred. Rehabilitation program begins in pre-operative period. The patient should be explained that it is at least as important as the surgery.

The use of autogenous hamstring tendons as a graft for anterior cruciate ligament reconstruction gives good results because of their advantages available. There is no gold standard for autogenous grafts. Quadruple semitendinous and gracilis tendon grafts are stronger and more rigid than normal anterior cruciate ligament during the implantation.

To conclude, ACL reconstruction with AperFix system, a new fixation system, was found as a useful method in the light of literature data and the results obtained when the findings and results of the study that we performed for the reconstruction of anterior cruciate ligament deficiency with single tunnel-dual-bundle technique and quadruple hamstring autograft. It is concluded that this system may be a good alternative due to the ease of the procedure and short duration of surgery compared to the methods used more often in the literature. However, as with all surgical procedures, it is required to see the long-term results of this new system in terms of restoring the knee bio-mechanic, proving its benefits for blocking the degeneration and assessing the long-term sustainability of the stable fixation. In our opinion, this factor should be considered as the most important weakness of our study.

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