ACTA ORTHOPAEDICA et TRAUMATOLOGICA TURCICA

ORIGINAL ARTICLE

Acta Orthop Traumatol Turc 2011;45(4):240-247
doi:10.3944/AOTT.2011.2402

Comparison of functional outcomes of two anterior cruciate ligament reconstruction methods with hamstring tendon graft

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Objective: The aim of this study was to compare the effects of Endobutton post-fixation and femoral (TransFix) transfixation in ACL reconstruction on lower extremity muscle strength, joint position sense, and knee stability.

Methods: Subjects who had undergone ACL reconstruction with hamstring tendon using Endobutton post-fixation (n=20, mean age: 26.5 years) or femoral transfixation (n=20, mean age: 29.9 years) were recruited to an ACL rehabilitation program. Twelve months after surgery, quadriceps and hamstring torque values were recorded using an isokinetic dynamometer. Computerized coordination and proprioception tests (Functional Squat System; Monitored Rehab System) were performed to determine the deficits in joint position sense. The anterior translation test was performed using a Kneelax 3 arthrometer to determine knee laxity.

Results: Side-to-side differences between groups for hamstring and quadriceps muscle strength, concentric and eccentric motor coordination and anterior tibial laxity were not significantly different ($p>0.05$).

Conclusion: No statistically significant differences in functional outcome were found 1 year after the ACL reconstruction using Endobutton post-fixation and femoral transfixation with hamstring tendon graft. Deficits in hamstring-quadriceps muscle strength, motor coordination and proprioception were still found in both groups. We therefore recommend that long-term follow-up and rehabilitation including neuromuscular exercises should be continued for longer than one year after ACL reconstruction.

Key words: Anterior cruciate ligament; Endobutton; hamstring graft; TransFix.

In orthopedics, one of the focuses of current research is surgery on the anterior cruciate ligament (ACL).[1] The aim of surgery is to restore the ACL function, to maintain the proprioceptive mechanisms lost as a result of injury, thus reducing the risk of osteoarthritis.[2]

Different types of autograft and allograft have been used in ACL reconstruction for many years. Recently, the hamstring tendon has become the preferred autogenous graft.[3,4] A range of methods and materials are used to fix the hamstring tendon in ACL reconstruction. Endobutton post-fixation (Smith & Nephew Inc., Andover, MA, USA) is one of the most common techniques used to fix the autograft in the lateral femoral cortex. In biomechanical studies, graft stiffness was reported to be 61±11 N/mm.[5] Femoral

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Submitted: December 21, 2009 **Accepted:** August 28, 2010

transfixation is another commonly used fixation method (TransFix; Arthrex, Inc., Naples, FL, USA). Graft stiffness has been reported as 240±74 N/mm with this method.[6] Clinical and cadaveric studies reporting on the stiffness of different fixation methods can be found in the literature, but so far nothing has been published comparing the functional results of these reconstruction methods.[6-9]

Functional performance-based evaluation is important to assess the effectiveness of surgery and rehabilitation. We therefore evaluated the performance of the knee joint under dynamic conditions by determining post-rehabilitation functional differences in muscle strength, muscle coordination and knee stability after Endobutton post-fixation and femoral transfixation.

Patients and methods

Forty subjects, who had undergone ACL reconstruction with hamstring tendon autografts using Endobutton post-fixation or femoral transfixation, were divided into 2 groups of 20 and enrolled into a clinical ACL rehabilitation program (Table 1). All subjects gave written informed consent, and the study was approved by the Medical Research Ethics Committee. Patients with multiple injuries and patients with a history of previous knee surgery or neuromuscular disorder affecting motor coordination and perception were excluded.

All below measurements were performed 12 months after surgery:

1- The quadriceps and hamstring torque values were recorded using an ISOMED 2000 isokinetic dynamometer (D&R Ferstl GmbH, Hemau, Germany).

2- Computerized coordination and proprioception tests were performed using the Functional Squat System (Monitored Rehab System, Haarlem, the Netherlands) to determine deficits in proprioception and neuromuscular coordination.

3- The anterior translation test was performed using the Kneelax 3 arthrometer (Monitored Rehab System, Haarlem, the Netherlands) to determine differences in anterior tibial translation.

The operated knee was compared with the non-operated side, and the deficit was calculated in percentage for all tests.

Surgery

Femoral transfixation: Autogenous quadrupled semitendinosus and gracilis grafts were used for ACL reconstruction. An oblique incision two fingerbreadths below the medial joint-line over the pes anserinus tendons was used to harvest the tendons. A hockey stick incision above the pes anserinus was used to elevate the insertion site of the tendons. Tendons were harvested with a tendon stripper and all muscle remnants were removed bluntly with scissors. Both ends of the tendons were sutured separately and grafts were tensioned with 15 lbs for at least 5 minutes on the table with a graft-tensioning system. Tibial and femoral tunnels were created. Suspension-type fixation was used on the femoral side and intratunnel fixation with bioabsorbable interference screws plus supplemental staples were used on the tibial side.

Endobutton post-fixation: Gracilis and semitendinosus tendons were harvested using a tendon stripper. The knee joint was then arthroscopically evaluated through standard arthroscopy portals. Femoral tunnels were opened at the 10 or 2 o'clock positions through a medial portal with a convenient width to

Table 1. Patient demographics.

	Age (year)±SD	Height (cm)±SD	Weight (kg)±SD
TransFix (n=20)	29.85±7.57	172.40±7.95	73.35±1.69
Endobutton (n=20)	26.45±9.23	174.20±6.01	71.20±3.00

Fig. 1. Patient position during motor coordination and proprioception tests [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

accommodate gracilis and semitendinosus tendons folded 4 times. Tibial tunnels were laid at 45 degrees to the ACL stump through graft incision. Prepared grafts were embedded intra-articularly through the tibial tunnel and fixed using an Endobutton loop at the femoral site and a bioabsorbable screw and a U-nail at the tibial site.

Postoperative rehabilitation

All patients started rehabilitation during the first week after surgery. Early range of motion was encouraged in the first 3 postoperative weeks. Patients were allowed weight-bearing as tolerated. Closed kinetic chain flexion exercises were performed to increase the range of motion in the direction of flexion. Prone hanging leg extension was applied to prevent extension limitation. Straight leg raise, isometric quadriceps sets, and hip abduction-adduction exercises were performed to increase quadriceps control. Cycling, Theraband strength training, mini squats, and coordination and balance exercises on the balance board and soft ground started 3-4 weeks after surgery. Standing mini squat and closed kinetic chain coordination exercises were continued during this period. Resistive knee flexion/extension exercises were introduced after 6-8 weeks. Patients used a brace for the first 6 weeks after surgery. Jogging was allowed at 16th weeks. Clinical follow-up appointments were planned after 6, 12, 16, 24 and 36 weeks to manage the rehabilitation program and to maintain patient motivation.

Assessment of strength

Patients in both groups were evaluated using the ISOMED 2000 isokinetic dynamometer (D&R Ferstl GmbH, Hemau, Germany). The patient was seated with the knees and legs flexed 90° to determine the isokinetic torque value of the hamstring and quadriceps during knee flexion and extension. The center of the knee joint was aligned with the center of the dynamometer using a laser-pointing device. After a 5 minute warm-up, the angular velocity was set at 60°/s. The patient was asked to push up the lever arm of the system 5 times as strongly as possible and return to the starting position. The same procedure was repeated at 180°/s with 10 repetitions after a break of one minute. The average maximum torque value was calculated. Differences in 'peak torque' and 'total work' of the operated and healthy knees were calculated as a percentage.

Assessment of motor coordination

Motor coordination was assessed using the Functional Squat System, a computerized horizontal leg-press system (Monitored Rehab System, Haarlem, the Netherlands). The patient was placed supine in a one-leg half-squat position on a horizontal leg-press machine, with the hip, knee and ankle joint flexed at 90° (Fig. 1). The patient was asked to perform a full-knee extension and return to the starting position. The maximum and minimum points of the movement were recorded during horizontal squat. Twenty percent of the individual body weight for each patient was applied as the resistance load and the test was started. Subjects were instructed to track the trajectory via a cursor shown on a monitor for 1 minute and had to perform coordinated knee flexion and extension using concentric and eccentric muscle contraction to complete the task correctly. The deviation from the route was calculated by the software. The procedure was performed with the healthy leg and injured leg after a one minute break. Differences in trajectory-tracking error and coordination deficit of the operated and healthy knee were calculated for both eccentric and concentric movement.

Assessment of proprioception

The patient was placed on a horizontal leg-press system in the same way and was asked to perform a full-knee extension and return to the starting position. The maximum degree of flexion and extension were recorded during the horizontal squat. Twenty percent of the individual body weight was applied as a resistance load. The patient was instructed to alter the squat position two times following a red cursor in response to a computer-generated blue route representing joint position. Afterwards, the red cursor disappeared and the patient was instructed to attempt to reposition the joint at the same angle without visual feedback. The difference between the points reached with and without visual feedback was calculated by the system. The procedure was performed with the healthy leg and injured leg after one minute of rest. Differences in the operated and healthy knee were calculated and described as a percentage.

Assessment of knee stability

Measurement of tibio-femoral movement in the anterior-posterior direction was performed using the

Table 2. Isokinetic strength deficits.

		Femoral transfixation		Endobutton post-fixation			
Quadriceps deficit		**X**	**±SD**	**Mean**	**±SD**	**t**	**p**
(180 °/s)	Peak torque (%)	16.96	±14.86	21.90	±14.82	-.1052	.299
	Total work (%)	17.14	±16.23	19.36	±16.91	-.424	.674
	Peak torque (%)	11.49	±12.32	16.08	±13.16	-1.140	.262
	Total work (%)	14.63	±13.31	16.22	±13.70	-.372	.712
Hamstring deficit		**X**	**±SD**	**Mean**	**±SD**	**t**	**p**
(180 °/s)	Peak torque (%)	7.31	±13.90	15.52	±14.45	-1.831	.075
	Total work (%)	6.14	±14.71	17.03	±22.84	-1.792	.081
	Peak torque (%)	7.31	±12.12	9.82	±12.06	-.655	.516
	Total work (%)	9.64	±14.76	12.09	±14.26	-.535	.596

SD: Standard deviation; t: t-test; p=0.05.

Kneelax 3 arthrometer (Monitored Rehab System, Haarlem, the Netherlands). The patient was placed in a semi-upright sitting position. The arthrometer was placed with the knee flexed at 20-30° and then bound tightly to the patient's leg. The patient's leg was drawn anteriorly with the thigh held in place. Anterior tibial translation was determined under a force of 132 N. The same procedure was repeated with the other knee. Differences in the anterior tibial translation of the operated and healthy knees were calculated in millimeters.

Statistical analysis

All data were analyzed using the independent sample t-test to compare dependent variables between groups (SPSS Software 15.0, SPSS Inc., Chicago, IL, USA). Level of significance was set at $p<0.05$.

Results

The difference in isokinetic hamstring and quadriceps peak torque and total work at 180°/s and 60°/s between the operated and healthy knees did not differ significantly between groups ($p>0.05$) (Table 2; Figs. 2 and 3). The difference in the eccentric and concentric parts of coordination tests, proprioception tests and anterior tibial translation between the operated and healthy knee did not differ significantly between groups ($p>0.05$) (Table 3; Figs. 4 and 5).

Discussion

The results of this study showed no difference between femoral transfixation and Endobutton post-fixation in terms of isokinetic strength one year after ACL reconstruction. An approximate 10% deficit in hamstring muscle torque of the operated and healthy

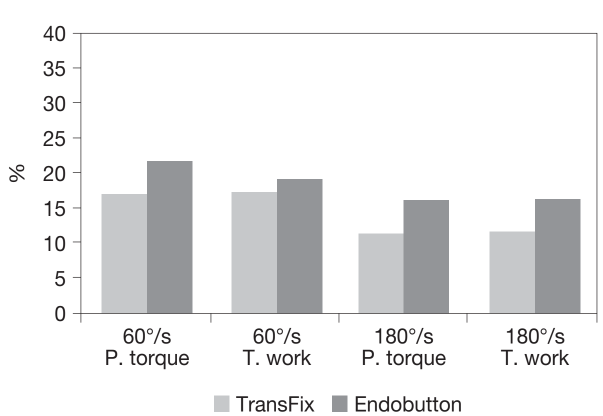

Fig. 2. Side-to-side deficits in knee extensor strength.

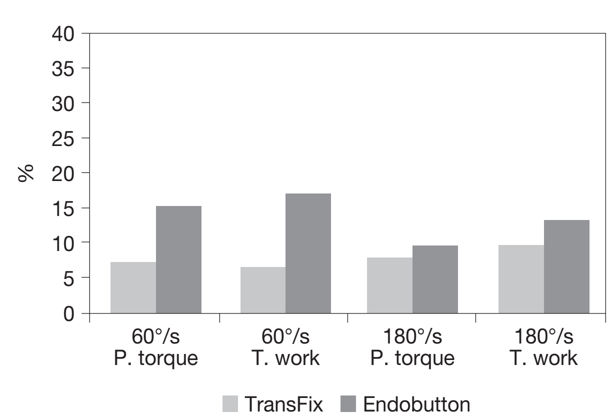

Fig. 3. Side-to-side deficits in knee flexor strength.

Table 3. Deficits in eccentric-concentric coordination, proprioception and anterior tibial translation.

	Femoral transfixation	Endobutton post-fixation		
	X ±SD	X ±SD	t	p
Eccentric coordination deficit (%)	16.47±13.87	15.31±14.69	.257	.799
Concentric coordination deficit (%)	18.35±21.86	16.45±10.43	.351	.728
Proprioception deficit (%)	73.72±81.032	74.58±121.33	-.424	.674
Anterior tibial laxity difference (mm)	2.63±1.55	2.46±1.49	.636	.712

SD: Standard deviation; t: t-test; p=0.05

knees was seen with both techniques. This finding is consistent with the strength deficits after ACL reconstruction seen in previous studies. Bizzini et al. reported a 10.4±3.6% deficit in hamstring muscle strength 11 months after ACL reconstruction with hamstring tendon grafts.[10] Aune et al. reported an approximate 15% deficit in hamstring strength after ACL reconstruction with hamstring tendon grafts one year after surgery.[11] Feller et al. reported that ACL reconstruction with hamstring tendon grafts resulted in an 8.7±17.1% hamstring strength deficit at Month 12.[12] Authors who have investigated long-term muscle-strength outcomes after ACL reconstruction have shown that hamstring strength deficit decreases and almost returns to normal 2 to 4 years after surgery.[13,14]

Our study also showed that the femoral transfixation group had a 10-15% deficit, while the Endobutton post-fixation group had a 15-20% deficit in quadriceps strength. Similar results have been reported in several previous studies investigating postoperative outcomes in ACL reconstruction with hamstring tendon grafts.[12,15-17] De Jong et al. noted a serious strength deficit in quadriceps muscle after ACL reconstruction with hamstring tendon grafts.[16] Although the deficit decreased between 6 and 12 months after surgery, a significant strength deficit still existed compared to preoperative measurements.[16] Kobayashi et al. reported that although muscle strength had increased by 17% at 60°/s and 9% at 180°/s between 12 to 24 months after surgery, patients still had remarkable hamstring and quadriceps strength deficits.[17] Feller et al. reported an 11.1 ±16.5% deficit in quadriceps strength at 12 months at 60°/s.[12] Studies reporting the presence of long-term quadriceps strength deficits after ACL reconstruction showed that this was the case after both patellar and hamstring tendon autografts and allografts.[10,18]

Quadriceps weakness occurs mainly not because of donor site morbidity, but damage to the receptor and neuromuscular activation systems.[19-21] Regardless of the graft type, weakness is therefore expected. Although the deficit in strength decreases over time, the muscle weakness continues even many years after

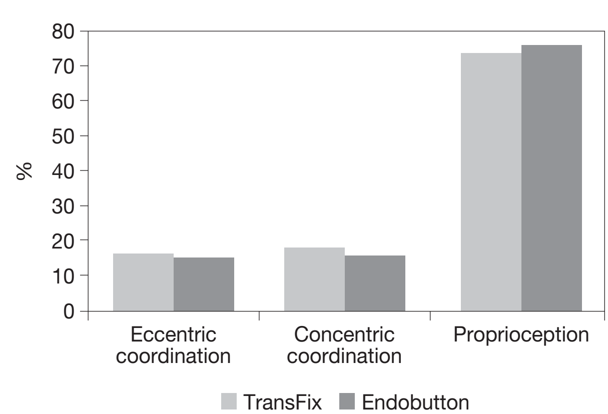

Fig. 4. Side-to-side deficits in motor coordination and proprioception.

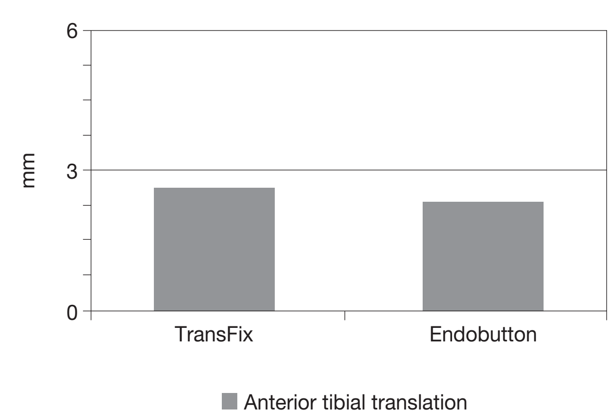

Fig. 5. Side-to-side differences in anterior tibial translation.

reconstruction.[22,23] Lautamies et al. showed that quadriceps and hamstring deficits persisted after both patellar tendon and hamstring tendon grafts after 5 years.[22] Jarvela et al. reported a quadriceps deficit of approximately 10% 7 years after reconstruction.[23]

A further important finding of our study was that both groups showed concentric–eccentric motor coordination deficits of 15-18% and proprioception deficits of approximately 70%. These low scores for the operated limb can be attributed to a loss of joint position sense after the ACL injury. The mechanoreceptors in the ACL play an important role in the proprioception of the knee joint.[2] Denti et al. demonstrated that ACL tears result in a decrease in the number of mechanoreceptors, starting 3 months after the injury.[24] The authors found only a few nerve endings after 9 months, which were then totally absent after one year.[24]

Although it is known that ACL injuries cause mechanoreceptor damage, studies investigating proprioceptive function show contradictory results. Some authors have reported decreased joint-position sense,[25-27] but others have found no difference in joint-position sense after injury.[28,29] Grob et al. found no correlation between the tests measuring joint position sense despite proven joint position sense assessments in the literaure.[30,31] The tests gave different results when the direction of movement or starting position was changed.[28,30] On the other hand, none of these proprioception tests are able to discriminate between the proprioceptive sense from ACL mechanoreceptors and the position sense from other soft tissues or the joint capsule. Thus, none of these tests can demonstrate specific outcomes with regard to ACL mechanoreceptors.[32] The motor coordination and proprioception tests used in the present study measured the knee joint under dynamic circumstances, in contrast to the studies which evaluated only the joint position sense.

The ACL is the main ligament preventing anterior tibial translation. Nevertheless, it allows some tibial displacement when external forces are increased. Gabriel et al. reported a 4±1.0 mm tibial translation with full extension and a 6.4±2.4 mm tibial translation at 60° flexion.[33] The ACL also allows an anterior translation of 3.7±2.2 mm at 15° flexion and 5.7 ±2.7 mm at 30° under the combined load of 10 Nm valgus and 5 Nm internal rotation.[33] Both groups of ACL reconstructed knees in our study showed less than 3 mm anterior translation when compared with the opposite side. Previous studies investigating the knee stability have reported similar results after ACL reconstruction.[11,12,34-36] Aune et al. showed differences of 2.8±2.6 mm between the operated and uninjured side one year after reconstruction with hamstring tendon grafts[11] and Feller et al. reported differences of 1.9±1.1 mm.[12] Marcacci et al. investigated the knee laxity in 50 patients after 5 years and reported a difference of less than 3 mm between the two sides in 76% of their cases, 3 to 5 mm in 18%, and more than 5 mm in 6%.[34] Aşık et al. reported that 95% of 204 patients showed differences of less than 5 mm between the operated and uninjured knees approximately 82 weeks after reconstruction.[35] Prodromos et al. measured anterior tibial displacement in 133 patients after ACL reconstruction with Endobutton post-fixation at 54 months and demonstrated that 86.7% had a difference of less than 3 mm and 3% had a difference of 4 mm between two sides.[36] Bizzini et al. measured anterior tibial stability using the Kneelax and found a difference of 2.7±0.7 mm for tibial displacement after ACL reconstruction with hamstring tendon grafts 11 months after surgery.[10] We found no studies that have compared knee stability after different methods of reconstruction with hamstring tendon grafts. Different surgical methods or fixation materials might, however, cause different biomechanical results.[37,38] Our results are therefore important as they demonstrated similar stability outcomes with different fixation methods.

A limitation of comparison with the opposite knee is the ignoring of the postoperative alterations in the unoperated knee. It is therefore only suitable for showing the amount of strength lost compared to the non-operated knee and not to the preoperative status.

No statistically significant differences between functional outcomes were found one year after ACL reconstruction using Endobutton post-fixation and femoral transfixation, based on the determination of isokinetic muscle strength, neuromuscular coordination, joint position sense and the anterior tibial stability. Deficits in hamstring-quadriceps muscle strength, motor coordination and proprioception were still found in both groups, indicating that complete recovery had not been achieved after 12 months. Rehabilitation programs and long-term follow-up should therefore last for longer than 12 months after ACL reconstruction.

Conflicts of Interest: No conflicts declared.

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