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Authors Serdar Toy*, Mehmet Cenk Turgut†, Vojnosanitetski pregled (2020); Online First December, 2020.

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Serdar Toy*, Mehmet Cenk Turgut†

* Ağrı Training and Research Hospital, Department of Orthopedics and Traumatology, Ağrı, Turkey.

† Erzurum City Hospital, Health Sciences University, Department of Orthopedics and Traumatology, Erzurum, Turkey.

Correspondence to: Serdar TOY, MD., Consultant Surgeon,
Department of Orthopedics and Traumatology, T. C. Ministry of Health Ağrı State Hospital, Central/Ağrı, Turkey;
E-mail address: serdartoy737@gmail.com;
Telephone number: +90 505 718 3926

ORCIDs:

Serdar TOY: https://orcid.org/0000-0001-8074-4672

Mehmet Cenk TURGUT: https://orcid.org/0000-0002-8642-6824
Abstract

Background/Aim. Anterior cruciate ligament rupture is a common orthopedic problem. In this article, we aim to investigate the effect of knee joint angle on biomechanical and clinical results during ligament fixation in anterior cruciate ligament reconstruction surgery. Methods. This study was planned prospectively. From December 2018 to January 2020, fifty-nine patients underwent anterior cruciate ligament reconstruction surgery. Those patients were divided into two groups. In the first group, ligament fixation was performed with the knee in semi-flexion. In the second group, ligament fixation was applied with the knee in full extension. Results. There was a significant difference between the results of the scores examined in the first group of patients before surgery and six months after surgery. When the results obtained from the patients in the second group were evaluated, a significant difference was found in the Lysholm and IKDC scores compared to the baseline level. The results obtained with the postoperative KT-1000 were found to be significantly better in the first group. Conclusion. The results of the group that ligament was fixed in semi-flexion were better. We recommend that ligament fixation be performed while the knee joint is semi-flexed during anterior cruciate ligament reconstruction surgery.

Key words: Anterior Cruciate Ligament; Biomechanics; Knee Joint Angle; Knee Kinematics; Knee Ligaments

Apstrakt

Uvod / Cilj. Puknuće prednjeg križnog ligamenta čest je ortopedski problem. U ovom radu želimo istražiti učinak kata zgloba koljena na biomehaničke i kliničke ishode tijekom fiksacije ligamenata u operaciji rekonstrukcije prednjeg križnog ligamenta. Metode. Ova studija je planirana prospektivno. Od decembra 2018. do januara 2020. pedeset i devet pacijenata podvrgnuto je operaciji rekonstrukcije prednjeg križnog ligamenta. Ti su pacijenti podijeljeni u dvije grupe. U prvoj grupi fiksacija ligamenata izvedena je koljenom u polu fleksiji. U drugoj grupi fiksacija ligamenata primijenjena je na koljeno u punom ekstenzijom. Rezultati. Postojala je značajna razlika između rezultata
ispitivanih rezultata u prvoj grupi pacijenata prije operacije i šest mjeseci nakon operacije. Kada su procijenjeni rezultati dobiveni od pacijenata iz druge skupine, utvrđena je značajna razlika u rezultatima Lysholma i IKDC u odnosu na početni nivo. Utvrđeno je da su rezultati dobijeni postoperativnim KT-1000 značajno bolji u prvoj grupi. **Zaključak.** Rezultati grupe koja je fiksirala ligament u polufleksiji bili su bolji. Preporučujemo da se fiksacija ligamenta izvrši dok je zglog koljena poluflektiran tokom operacije rekonstrukcije prednjeg križnog ligamenta.

**Ključne reči:**

Prednji križni ligament; Biomehanika; Kut zgloga koljena; Kinematika koljena; Ligamenti koljena

**Introduction**

Anterior cruciate ligament (ACL) rupture is one of the common orthopedic problems. It is the most injured structure in the knee after meniscus injuries. Treatment of ACL rupture is performed conservatively or surgically. Recently, arthroscopic surgical techniques and rehabilitation principles have advanced. So, surgical treatment of ACL rupture has become more common.

The most common causes of ACL injury are sports injuries. It is an injury that we encounter more and more every day due to the increasing sports activities. Surgery of ACL reconstruction is routinely used in active patients. In this surgery, we aim to return the patient to daily sports activities as soon as possible. Furthermore, performing surgery protects the patient from the traumas (1).

Successful ACL reconstruction surgery depends on many critical factors (2-5). During ligament fixation, the angle of the knee is an essential factor for the quality of surgery (6-8). There is still no consensus on this issue. It remains a topic that is frequently discussed at meetings. The range defined in the literature ranges from 15 degrees of flexion to full extension (9).
In this study, we aimed to evaluate whether the angle of the knee joint creates a clinically and biomechanically significant difference in the postoperative period during fixation in ACL reconstruction surgery.

**Methods**

Ethics committee approval was received for this study. Between December 2018 and January 2020, a total of 110 patients who applied to our clinics for ACL rupture was evaluated. The inclusion criteria were as follows: 1) patients were between the ages of 16 and 55. 2) Unilateral primary ACL rupture diagnosed with physical examination and magnetic resonance imaging (MRI). 3) Patients could have concomitant meniscus tears. The exclusion criteria were as follows: 1) The ACL rupture was accompanied by neurovascular injuries of the knee. 2) The ACL tear was associated with lesions of the posterior cruciate ligament (PCL), medial collateral ligament, lateral collateral ligament, or posterolateral corner of the knee. 3) The patient had systemic autoimmune disease, connective tissue disease, neoplasm, infection, severe hypertension, coronary heart disease, diabetes, or other known diseases that could affect the results of the synovial fluid analysis. Considering the exclusion criteria, 62 patients remained. These 62 patients were divided into two groups using https://www.randomizer.org/. An informed consent form was obtained from the patients before the operation. There were 31 patients in group 1. Ligament fixation was performed in these patients while the knee joint was in semi-flexion (30 degrees). There were 31 patients in the second group. In group 2, Ligament fixation was performed with the knee joint at full extension (180 or 0 degrees).

During follow-ups, one patient in group 1 and two patients in group 2 was excluded from the study. These three patients were excluded due to incomplete follow-up. Thus, the study was completed with 59 patients.

Lysholm scoring, Tegner activity scoring and International Knee Documentation Committee (IKDC) tests were applied to each patient before the surgery and the postoperative 6th-month. The results obtained from those tests were noted in the patients' files. At the postoperative 6th-month controls, the patients were measured by applying a 15-pound (67 Newton) force with the KT-1000 knee arthrometer (KT-1000). KT-1000 is an objective tool for evaluating ACL reconstruction. KT-1000 measures anterior tibial
motion relative to the femur. The test involves attaching the KT-1000 to the leg, pulling the tibia forward, and measuring the amount of movement in millimeters (mm). The results obtained with the KT-1000 were noted. By analyzing those results, it was tried to determine whether there was a significant difference between the two groups.

**Surgical Intervention**

All patients were taken to the operating table in a supine position. The patients’ knees were suspended from the table to allow 0-120 degrees of range of motion. Antibiotic prophylaxis was performed with 1 g of cefazolin 30 minutes before surgery. An anesthesiologist performed a spinal, combined or general anesthesia, taking into account the patient’s suitability and desire. Knee instability tests (Anterior Drawer, Lachman, Pivot-Shift) were reassessed after anesthesia. The extremity of the patient to be operated was cleaned with a suitable antiseptic solution. After the leg was covered with sterile drapes, it was elevated, and a sterile tourniquet was applied (Figure 1).

The surgical procedure was started arthroscopically by opening standard anterolateral and anteromedial portals. Besides the ACL, PCL structures, meniscus and cartilage structures were evaluated arthroscopically. After it was seen that the ACL was ruptured, the tendon graft taking procedure was started.

When taking the hamstring tendon autograft, an oblique or longitudinal skin incision was made approximately 2 cm medial to the tibial tubercle and 3-4 cm below the medial joint space (Figure 2). After the skin and subcutaneous were passed, the pes anserinus fascia was cut from the bone with a reverse L-shaped incision and released with the help of the periosteal elevator. Under fascia, semitendinosus and gracilis tendons were palpated and separated from the fascia by blunt dissection. Then, a sign suture was placed at the end of the tendons and grafts were removed with a tendon stripper (Figure 3).

Semitendinosus and gracilis that taken as grafts were wetted with saline. Their muscular portions were cleaned. The proximal and distal parts of the tendons were tightened with 2/0 vicryl. After suturing the ligaments, the graft was stretched for about 10 minutes to minimize elongation and stress in the joint.
Notchplasty is still controversial and depends on intraoperative evaluation by the surgeon. Impingement may occur between the graft and the intercondylar notch. The relatively large graft is one of the main reasons. Notchplasty is performed to prevent this impingement and to determine the intra-articular exit location of the femoral tunnel. How much bone will be resected depends on the diameter of the graft, the shape of the intercondylar notch, the localization of tibial tunnel, and the presence of osteophytes (Figure 4).

Determining the location of the tibial tunnel is an essential step in ACL reconstruction. Site of the tibial tunnel is critical in terms of whether the graft will be trapped in intercondylar notch and whether it is in the proper direction. The outlet of the tibial tunnel in the joint should be as close as possible to the medial tibial protrusion, and it should be continuous with the interior of the anterior horn of the lateral meniscus. It should be 5-7 mm in front of the posterior cruciate ligament. By adjusting the tibial guide angle to 55 degrees, one end was inserted through the anterolateral arthroscopic portal and placed approximately 5-7 mm in front of the posterior cruciate ligament (Figure 5). The guidewire was sent after the other end of the tibial guide was placed in the graft incision. The tibial tunnel was opened with a drill suitable for the graft diameter with the help of a guidewire. The intraarticular exit point of the tunnel was flattened with a curette to prevent damage to the ligament.

For the femoral tunnel, a new portal was opened from the medial of the anteromedial portal, and the guidewire was placed in the adhesion of anteromedial (AM) and posterolateral (PL) bands of ACL with the freehand technique. The guidewire was sent, and the lateral cortex of the femur was drilled and crossed the skin. Tunnel length was measured by drilling with a 4.5 mm cannulated drill over this guidewire. The femoral tunnel was opened with the endobutton cannulated drill by the size of the graft by deciding how long the graft will remain in the tunnel (Figure 6). A doubled PDS suture was passed through the guidewire and pulled off the end of the wire from the skin. Thus, the cut ends of the PDS were removed from the skin. The loop-shaped end of PDS was held with the other hand, and the cut ends were passed through the loop and held with a clamp.

The ends of the PDS suture were separated from each other, and the loop-shaped tip was removed from the tibia through the tibial tunnel with the help of a holder. The graft
was loaded on the PDS loop end with the help of ethibond sutures attached to the endobutton and held by the cut PDS end from the femoral side until the ethibond sutures came. Then, these ethibond sutures were withdrawn, accompanied by a scope where the endobutton passed through the femoral tunnel and sat in the lateral cortex of the femur. Knee flexion and extension were performed to prevent stress relaxation of the graft. In patients in group 1, the ligament was fixed to the tibial tunnel with an interference screw while the knee was at semi flexion (30 degrees) (Figure 7) and then fixed with a U staple approximately 1 cm below the tibial tunnel. The same procedures were performed in patients in Group 2, with the knee at full extension (180 or 0 degrees) (Figure 8). After fixation, tension and impingement status of the new tendon were checked by arthroscopy (Figure 9).

Postoperative Rehabilitation

Rehabilitation in ACL reconstruction surgeries should be started before surgery and should continue in the postoperative period. The purpose of pre-operative exercises is to achieve an equal range of motion compared to the intact knee, especially if there is an extension loss, to reduce swelling and increase the extensor muscle strength. After the operation, patients are put on an angle-adjustable hinged knee brace to try to get full extension and flexion up to 90 degrees between 0-3 weeks. It includes closed chain exercises to achieve good quadriceps muscle strength and full extension. Excessive strains during this period can increase pain and inflammation. It is tried to increase the range of motion between 3-6 weeks. In this time interval, the patient returns to normal walking and daily activities. It is allowed to start running after six weeks and return to sports after the sixth month.

Statistical Analysis

While the categorical data of the cases forming the groups before and after the treatment are stated as frequency and percentage measurements; arithmetic mean, standard deviation, median, minimum and maximum values were calculated. Statistical evaluation was done using SPSS for Windows 23.0 (Armonk, NY: IBM Corp. 2015). The distribution properties of the data were determined by Shapiro Wilks test, and variance homogeneity was assessed by Levene test. The data obtained from both groups were evaluated according to the distribution characteristics of the appropriate parametric or non-parametric tests. Chi-
Square and Paired Samples t-test were used for intra-group comparison. Comparison of both groups before and after treatment was made using Wilcoxon, Mann-Whitney U test and Unpaired Samples t-test. p<0.05 value was accepted as statistically significant.

Results

During the anterior cruciate ligament reconstruction, the preoperative and postoperative clinical results of the patients in the first group that were detected while the knee joint was in semi-flexion were evaluated. Significant improvement was discovered in the Tegner activity scoring of the patients in the postoperative period (p:0.000; p <0.001) (Table 1). When the results of the Lysholm scoring of the patients in the same group were evaluated, it was determined that the patients improved significantly compared to the baseline level (p:0.000; p<0.001) (Table 1). According to the IKDC scoring test, there was a significant improvement compared to the baseline level (p:0.000; p<0.001) (Table 2).

Clinical tests of patients in Group 2 before and after surgery were evaluated. When we examined the results of patients preoperatively and six months after surgery, there was no significant difference in the Tegner activity scoring test (p:0.276; p>0.05) (Table 1). When the Lysholm score results of the patients in the same group were evaluated, a significant improvement was found between the baseline and the postoperative period (p:0.000; p<0.001) (Table 1). According to the IKDC system, there was a significant improvement compared to the baseline level (p:0.000; p<0.001) (Table 2).

When the results of postoperative Tegner activity scoring of all patients were evaluated, there was a significant difference between them according to the baseline level (p:0.000; p<0.001) (Table 3). When the results of the postoperative Lysholm scoring of the patients were evaluated, a significant improvement was found compared to the baseline level (p:0.000; p<0.001) (Table 3). When the results obtained with KT-1000 at the 6th month of the patients were evaluated, there was a significant difference in favour of the patients in group 1 (p:0.000; p<0.001) (Table 1).

Discussion

Ligament fixation when the knee joint is in full extension may lead to knee extension loss and prevent graft lengthening. Clinical and biomechanical studies have reported that graft fixed at 30 degrees of flexion restores knee stability better than graft
fixed at full extension (9-11). Höher et al. (12), evaluated the anterior translation of the tibia with a robotic sensor system in the cadaver knees and found that graft fixed at 30 degrees of flexion provided better knee kinematics than graft fixed at full extension. In their biomechanical cadaver study, Debandi et al. (6), found similar results in terms of knee stability between graft fixed at full extension in anatomical anterior cruciate ligament reconstruction surgery and non-anatomic anterior cruciate ligament reconstruction.

In a clinical study, Asahina et al. (13), compared ACL ligament fixed at semi-flexion (30 degrees) with ligament fixed at full extension (180 or 0 degrees). They reported that the knee stability (KT-1000 arthrometer and manual pivot-shift test) and arthroscopic appearance (i.e., volume, tension, and synovial coverage) of the ACL ligament were superior in the group with the graft fixed at semi-flexion. Shi et al. (14) reported the order of graft fixation in double-bundle ACL reconstruction affected graft loading, but did not affect knee kinematics.

In this study, considering the scoring tests, no significant difference was found between the two groups. However, it was found that the results obtained with the KT-1000 were better than those of the patients whose graft fixation was performed while the knee joint was in semi-flexion. The graft loses volume during the rehabilitation process in the group with the graft fixed at full-extension. When we performed arthroscopy again in three independent patients with meniscal repair due to non-union and mechanical symptoms, we had the opportunity to examine the grafts arthroscopically. It was observed that the graft volume was preserved more in patients with graft fixed at semi-flexion. This observed situation was in support of the result we find.

**Conclusion**

In this study, we found that graft fixed at 30 degrees of flexion provided better knee kinematics than graft fixed at full extension. We recommend performing graft fixation during the anterior cruciate ligament reconstruction surgery with the knee joint at 30 degrees of flexion.
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- **Conflict of interest**: The authors declare that there is no conflict of interest.

- **Ethical approval**: Approval of the study protocol was obtained by the local ethics committee.

- **Informed consent**: Informed consent was obtained from all individual participants included in the study.

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TABLES
**Table 1:** Comparison of the scores of both groups

|                  | Group 1 | Group 2 | P value |
|------------------|---------|---------|---------|
| **Groups**       |         |         |         |
| **N:**           | 30      | 29      |         |
| **TEGNER**       |         |         |         |
| (pre-op)         | 5.27±1.89 | 5.24±1.02 | 0.949 |
| (R: 3-10)        | (R: 3-9) |         |         |
| **TEGNER**       |         |         |         |
| (post-op)        | 4.73±1.66 | 5.07±1.41 | 0.407 |
| (R: 3-9)         | (R: 3-9) |         |         |
| **p-value**      | 0.000*  | 0.276   |         |
| **LYSHOLM**      |         |         |         |
| (pre-op)         | 53.97±5.90 | 53.62±5.69 | 0.820 |
| (R: 44-64)       | (R: 44-64) |         |         |
| **LYSHOLM**      |         |         |         |
| (post-op)        | 88.80±7.77 | 84.83±10.00 | 0.093 |
| (R: 55-99)       | (R: 55-94) |         |         |
| **p-value**      | 0.000*  | 0.000*  |         |
| **KT-1000**      |         |         |         |
| (R: 1-4)         | 1.77±0.77 | 2.24±0.51 | 0.000* |
| (R: 1-3)         |         |         |         |

* Wilcoxon Test; p<0.001

**Table 2:** Comparison of IKDC scores of both groups

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13
### Table 3: Comparison of the scores of all patients

| All Patient (n=59) | PRE-OP | POST-OP | p-value |
|-------------------|--------|---------|---------|
| TEGNER            | 5.25±1.51 (R:3-10) | 4.90±1.53 (R:3-9) | 0.000* |
| LYSHOLM           | 53.80±5.75 (R:44-64) | 86±9.08 (R:55-99) | 0.000* |
| IKDC              | 2.00±0.69 (R:1-4) |         |         |

*Paired-Samples T test, p<0.001
FIGURES

Figure 1. Sterile preparation of the surgical field

Figure 2. Skin incision for Hamstring Tendon Graft
Figure 3. Hamstring Tendon Graft Removal

Figure 4. Arthroscopic Notchplasty View

Figure 5. Placement of Intraarticular Tibial Tunnel
Figure 6. Femoral Tunnel Opening with Free Hand Method
Figure 7: The tendon was stretched through the tunnel (A). The graft was fixed at semi flexion (B). After fixation (C).
Figure 8: Tendon fixation while the knee is in full extension (A, B)
Figure 9. Appearance and Control of Tendon After Fixation

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