



# Clinical experience with combined reconstruction of the anterior cruciate and anterolateral ligaments of the knee in sportsmen

Evgeniy Nikolaevich Goncharov<sup>1,2</sup> · Oleg Aleksandrovich Koval<sup>2</sup> · Vadim Erikovich Dubrov<sup>3</sup> · Eduard Nikolaevich Bezuglov<sup>4</sup> · Anastasiya Mikhaylovna Filimonova<sup>2,5</sup> · Nikolay Gavriilovich Goncharov<sup>1,2</sup>

Received: 28 June 2019 / Accepted: 29 August 2019 / Published online: 11 September 2019  
© SICOT aisbl 2019

## Abstract

**Background** Rupture of the anterior cruciate ligament (ACL) is one of the most common sports injuries of the knee joint. Today, we have a large number of approaches to arthroscopic reconstruction of the anterior cruciate ligament that lead to successful outcomes and allow the patients to return to a significant level of activity post-operatively. Nevertheless, the return to competitions rate stays relatively low. The functional state is thought to be dependent on rotational and anteroposterior stability of the knee. These data encourage search for methods of additional stabilization of the knee joint, one of them being extra-articular tenodesis, or reconstruction of anterolateral ligament of the knee.

**The aim of the study** To evaluate medium-term results of combined simultaneous arthroscopic reconstruction of anterior cruciate ligament and anterolateral ligament of the knee joint in sportsmen and to access the probability of return to competitions.

**Materials and methods** The surgeries were performed in 2014–2015 in 50 patients who fulfilled the entry criteria: 20 patients (including 10 professional sportsmen) underwent arthroscopic ACL reconstruction together with reconstruction of anterolateral ligament—group 1 (main group), and 30 patients (including 10 professional sportsmen) underwent arthroscopic ACL reconstruction—group 2 (control group).

**Results** Group 1: All patients of group 1 were able to return to the pre-operative sports level in two years after the surgery. The mean Tegner Lysholm score was  $72.6 \pm 6.45$  (hereinafter, SE—standard error) before the surgery and  $97.4 \pm 1.18$  after the surgery. The mean IKDC score was  $63.1 \pm 4.8\%$  before the surgery and  $96.3 \pm 1.8\%$  after the surgery. Group 2: 20 of 30 patients (66.7%) returned to the pre-operative level of activity and returned to competitions (if they were professional sportsmen) in a year after the surgery. Five of ten patients (50%) (professional sportsmen) returned to competitions. Fifteen of 20 patients (75%) (amateur sportsmen) also returned to competitions. The mean pre-operative Tegner Lysholm score was  $69.6 \pm 3.5$ , and the mean post-operative score was  $92.1 \pm 3.9$ . The mean pre-operative IKDC score was  $73.4 \pm 3.2\%$ , and the mean post-operative score was  $90.3 \pm 3.7\%$ .

**Conclusion** The results of the study show that more patients with higher functional demands and more professional sportsmen returned to sports. Despite the results of our and other foreign studies, a need remains for studies that will compare outcomes of ALL reconstruction with the same surgical technique in homogenous groups of patients.

✉ Oleg Aleksandrovich Koval  
drkovaloa@gmail.com; ckb@ckbran.ru

Evgeniy Nikolaevich Goncharov  
goncharoven@gmail.com; rmapo@rmapo.ru

Vadim Erikovich Dubrov  
vdubrov.2015@mail.ru; info@rector.msu.ru

Eduard Nikolaevich Bezuglov  
e.n.bezuglov@gmail.com; info@mma.ru

Anastasiya Mikhaylovna Filimonova  
nakimkina@mail.ru

Nikolay Gavriilovich Goncharov  
goncharovng57@gmail.com

<sup>1</sup> Russian Medical Academy of Continuous Professional Education, Barrikadnaya st., 2/1, 123242 Moscow, Russia

<sup>2</sup> Traumatology and Orthopedics Center, Central Clinical Hospital of the Russian Academy of Sciences, Litovskiy blvd., 1a, 117593 Moscow, Russia

<sup>3</sup> Department of the Fundamental Medicine Faculty, Lomonosov Moscow State University, Leninskie gory, 1, 119991 Moscow, Russia

<sup>4</sup> Department of Sport Medicine, I.M. Sechenov First Moscow State Medical University, Trubetskaya st., 8c2, Moscow, Russia

<sup>5</sup> Radiology Unit of Diagnostocal Center, Central Clinical Hospital of the Russian Academy of Sciences, Litovskiy blvd., 1a, 117593 Moscow, Russia

**Keywords** Anterolateral ligament · Sport · Back to sport · Knee instability · Anterior cruciate ligament · Reconstruction of anterior cruciate ligament · Reconstruction of anterolateral ligament

## Introduction

Rupture of the anterior cruciate ligament (ACL) is one of the most common sports injuries of the knee joint and is seen in 68.6/100,000 people annually [1]. Some authors report that the number of patients with isolated and combined injuries of ACL makes up to 0.3–1% of the Russian population [2, 3]. The techniques of arthroscopic ACL reconstruction have been improving continuously since the 1980s; new surgical techniques, equipment, and materials appear [4]. Today, we have a large number of approaches to arthroscopic reconstruction of the anterior cruciate ligament that lead to successful outcomes and allow the patients to return to a significant level of activity post-operatively [5, 6]. Nevertheless, the return to competitions rate stays relatively low and equal about 55% (44–72%) [7–9]. These low numbers depend on multiple factors. One of the causes is the residual rotational laxity, which is seen in 25–30% cases of ACL reconstruction [10, 11]. The functional state is thought to be dependent on rotational and anteroposterior stability of the knee joint [12, 13]. These data encourage search for methods of additional stabilization of the knee joint, one of them being extra-articular tenodesis, or reconstruction of anterolateral ligament of the knee.

The anterolateral ligament contributes to the rotational stability of the knee joint, which has been proven in many anatomical and biomechanical studies [14–16]. Tear to the anterior cruciate ligament is known to often come with injury of the anterolateral ligament [17]. Today, we have various techniques of the anterolateral ligament reconstruction [18–20].

**The aim of the study** The aims of the study are to evaluate medium-term results of combined simultaneous arthroscopic reconstruction of the anterior cruciate ligament and anterolateral ligament of the knee joint in sportsmen and to access the probability of return to competitions.

## Materials and methods

The design of this study is a single-center prospective longitudinal comparative controlled study.

The surgery was performed in 2014–2015 in 50 patients who fulfilled the entry criteria:

Twenty patients (including 10 professional sportsmen) underwent arthroscopic ACL reconstruction together with reconstruction of anterolateral ligament—group 1 (main group).

Thirty patients (including 10 professional sportsmen) underwent arthroscopic ACL reconstruction—group 2 (control group).

The surgical treatment was performed with the use of identical technique, instruments, and consumables. Group 1 was treated by one surgeon. Group 2 was treated by three surgeons of the unit, including the author of this publication.

This study used a technique of anatomic reconstruction of the anterolateral ligament. Extra-articular tenodesis was not performed at all.

The inclusion criteria are the following:

- Workouts at least three times a week.
- Participation in competitions.
- Professional sports activities.
- Age from 16 to 40 years old.
- No previous surgical treatment of the study knee joint.
- Consent to MRI of the knee joint before the surgical treatment.
- No neurological and psychological disorders.
- Consent to filling in the patient-reported outcomes (PROs) and participation in the study.

The function of the knee joint was evaluated by the physical examination, life history and case history, results of the functional tests, MRI results, and responses to the PROs before the surgery and two years after the surgery.

In addition, weight (weight more than 80 kg was preferable) and height (more than 180 cm was preferable) were measured in group 1. These parameters may increase the rotational load and create a “lever” on the knee joint. These factors may promote the joint injuries and rotational instability (evaluated in the pivot-shift test).

## Surgical technique

Our surgical technique of reconstruction of the knee joint anterolateral ligament is somewhat equivalent to the one described by J. Chahla et al. [20], with the following aspects being different.

1. *Surgical access.* We performed an additional cut of about 5 cm in the area of the lateral condyle of the femur. The access that was used to take the patellar tendon graft for reconstruction of the anterior cruciate ligament was also used to take the graft for reconstruction of the anterolateral

ligament and formation of the distal tunnel to lock this graft into place.

2. We did not form the tunnels of the anterolateral ligament with the guide which was used to form the tibial tunnel during the ACL reconstruction. The tunnels were formed directly along the guide pin.
3. The technique used to form proximal (femur) tunnel allows us to find the centre of rotation. The center of rotation is a position of the knee in which the anterolateral ligament is stretched equally at various knee flexion/extension angles.
4. The proximal and distal ends of the graft are sutured with a biodegradable material.
5. We use interference screws of different diameter.
6. The femur screw is installed with the knee joint fully extended.

We used a patellar tendon autograft with two bone blocks for ACL reconstruction in all patients. The femoral tunnel was formed through the anteromedial port. The bone tunnels were 10 cm in diameter. The graft was fixed by a classic procedure with biodegradable interference screws (polylactic acid/hydroxyapatite composite) of different length:  $8 \times 25$  mm in the femur tunnel and  $8 \times 30$  mm in the tibial tunnel. The bone blocks were positioned correctly within the tunnels in both groups. The incorrect position might have required us to modify the surgical technique or the graft fixation.

In group 1, the first step (ACL reconstruction) was followed by the second one—reconstruction of the anterolateral ligament. The gracilis or semitendinosus tendon was taken as the ALL graft through the access that was used to take the ACL graft. A pin was inserted in the point located on the lateral condyle of tibia, 1 cm lower than the joint line, and in the middle of the line from Gerdy's tubercle to the tibial head. An  $8 \times 25$  mm tunnel was formed along this pin. The distal end of the ALL graft was put in the tunnel and fixed with a biodegradable interference screw ( $8 \times 25$  mm, polylactic acid/hydroxyapatite) (Fig. 1).

We performed an about 5-cm cut in the area of the lateral condyle of the femur and reached the fascia lata layer by layer. We made a 4–5-cm longitudinal cut of the fascia lata and reached the lateral condyle and epicondyle of the femur (Fig. 2).

The forceps were passed from the lateral condyle of the femur below the iliotibial band so that the branches exited at the tunnel created on the tibia. The proximal end of the graft was drawn out with the forceps near the lateral condyle of the femur (Fig. 3).

An eye pin was installed 1 cm lower and proximal to the center of the lateral epicondyle. The proximal end of the graft was turned around the pin, then the knee was flexed and extended to confirm that the graft was in the center of rotation (i.e., position of the graft in which the latter is stretched equally at various knee flexion/extension angles) (Fig. 4).



Fig. 1 Fixation of the distal end of ALL graft

After the center of rotation was confirmed, the pin was drawn through the middle of the medial condyle of the femur. An  $8 \times 25$  mm tunnel was formed over the pin. Thirty centimeters of the proximal graft end was sutured with a biodegradable material. The threads were passed through the eye of the pin, and the pin was withdrawn on the opposite side. Thus, the proximal graft end was immersed in the femoral channel and the tension was applied to the graft with the threads that were withdrawn on the opposite side. At last, the graft was locked in place with biodegradable interference screw with the knee fully extended. The position and tension of the graft were assessed before suturing (Fig. 5).



Fig. 2 Planning the access to the lateral condyle of the femur



**Fig. 3** The proximal end of the ALL graft drawn out near the lateral condyle of the femur

### Post-operative management

The post-operative management protocol was identical in both groups. The orthoses were not used in the post-operative period. The patients were allowed to walk with full support of the treatment limb the day after the surgery. Bed rest was recommended for three weeks after the surgery, followed by passive rehabilitation of the range of motion. The knee flexion angle was at least 90° in both groups six weeks after the surgery. Running on an even surface and gym workouts were allowed in two months. The patients were allowed to return to sport level of activities after at least eight months. The patients performed follow-up visits in 12 and 30 days and then in three, six, 12, and 24 months after the surgery. The IKDC and



**Fig. 4** The centre of rotation with the knee joint bent at 90°



**Fig. 5** Assessing tension of the anterolateral ligament graft

Tegner Lysholm scales were completed before the surgery and in 24 months after the surgery.

### Statistical analysis

The descriptive statistical data were collected, pooled, and summarized.

Significance of the difference of means was evaluated with the Student's *t* test. The data were analyzed in SPSS software.

### Results

#### Group 1

Twenty patients were included in this group. Eighteen of 20 patients were available for the follow-up in the early and later post-operative periods. One patient was lost for follow-up after the sutures were removed. Another patient was excluded from the study because of a sepsis complication that was caused by the patient not following the recommendations. Two of 18 patients reported minor pain and discomfort (score 1–3 by pain VAS) in the anterior segment of the knee joint during physical activity in 24 months after the surgery. Pivot-shift test showed 0°, and Lachman test result was less than 3 mm in all patients in this group.

So, all patients of group 1 were able to return to the pre-operative sports level into two years after the surgery.

Tegner Lysholm and IKDC scales were completed before and after the surgery. The mean Tegner Lysholm score was  $72.6 \pm 6.45$  (hereinafter, SE—standard error) before the surgery and  $97.4 \pm 1.18$  after the surgery. The mean IKDC score was  $63.1 \pm 4.8\%$  before the surgery and  $96.3 \pm 1.8\%$  after the surgery.

## Group 2

All 30 that were included in group 2 were available for follow-up in the early and late post-operative periods. Five of 30 patients reported minor pain and discomfort (score 1–3 by pain VAS) in the anterior segment of the knee joint during physical activity in 24 months after the surgery. Four of 30 patients reported “lack of confidence” in the joint. Pivot-shift test showed 0° in 19 patients, 1° in ten patients, and 2° in one patient. Lachman test result was less than 3 mm in 17 patients, 3–5 mm in 11 patients, more than 5 mm in two patients.

Twenty of 30 patients (66.7%) returned to the pre-operative level of activity and returned to competitions (if they were professional sportsmen) in a year after the surgery. Five of ten patients (50%) (professional sportsmen) returned to competitions. Fifteen of 20 patients (75%) (amateur sportsmen) also returned to competitions. The “lack of confidence” of the patients in group 2 may be caused by positive results of the pivot-shift test and Lachman test of various degrees in 24 months after the surgical treatment. The mean pre-operative Tegner Lysholm score was  $69.6 \pm 3.5$ , and the mean post-operative score was  $92.1 \pm 3.9$ . The mean pre-operative IKDC score was  $73.4 \pm 3.2\%$ , and the mean post-operative score was  $90.3 \pm 3.7\%$ .

The mean values were compared between the two groups of patients (the samples were independent) that received different treatments (group 1—arthroscopic reconstruction of the anterior cruciate ligament together with the reconstruction of the anterolateral ligament and group 2—arthroscopic reconstruction of the anterior cruciate ligament).

The data was analyzed in SPSS software. The main parameters are outlined in Table 1.

H0 hypothesis: No statistically significant differences were seen in TL and IKDC scores of the general population of patients with rupture of the anterior cruciate ligament.

In summary, TL values were  $92.1 \pm 3.935$  in group 2 and  $97.4 \pm 1.184$  in group 1. IKDC values were  $90.3 \pm 3.739$  in

group 2 and  $96.3 \pm 1.799$  in group 1. Obviously, the confidence intervals of TL and IKDC values of the two groups do not overlap. The differences between the groups may be considered statistically significant. One hundred percent of the patients in the main group returned to competitions. 66.7% of the patients in the control group returned to competitions, including 50% of the professional sportsmen.

## Discussion

Results of our study show that simultaneous reconstruction of the anterior cruciate ligament and the anterolateral ligament increase rotational stability of the knee and allow the patients to return to the pre-injury level of physical activity. On the one hand, isolated arthroscopic ACL reconstruction allows the patients to return to the prior activities of the daily living [21, 22] and to amateur sports activities. Meta-analyses show that 81–85% of the patients return to amateur sports after arthroscopic ACL reconstruction. But only 53.4–65.0% of the professional sportsmen return to pre-injury level of sports activities, and only 44–55% return to competitions [9, 22]. Active patients and professional sportsmen are not satisfied with these numbers. These results are shaped by a wide range of factors, including concomitant injuries of intra- and extra-articular structures that influence the recovery and prognosis, in compliance with the recommendations and rehabilitation protocols, and psychological reasons. However, the residual instability after ACL reconstruction is not the least of these factors [12, 13, 23], and the risk of allograft rupture in patients of less than 20 years old is up to 16.4% [24]. Notably, the risk of the recurrent rupture is 1.8 to 14% after isolated ACL reconstruction [25, 26]. Also, a positive pivot-shift test has a negative impact on knee function [13, 23]. There is an issue of a potential post-traumatic gonarthrosis after ACL reconstruction as compared to the intact limb, which may be caused by microinstability that leads to damage to the articular

**Table 1** Mean values and confidence intervals for two independent samples (confidence level—95%)

Parameters	Group 2 ( <i>n</i> = 30)				Group 1 ( <i>n</i> = 18)			
	Pre-operative		Post-operative		Pre-operative		Post-operative	
	TL	IKDC	TL	IKDC	TL	IKDC	TL	IKDC
Mean	69.6	73.4	92.1	90.3	72.6	63.1	97.4	96.3
Standard deviation	9.409	8.586	10.538	10.014	12.962	9.645	2.382	3.617
Dispersion	88.530	73.726	111.059	100.285	168.016	93.031	5.673	13.084
<i>N</i>	30	30	30	30	18	18	18	18
<i>t</i> test	2.045	2.045	2.045	2.045	2.110	2.110	2.110	2.110
Standard error of mean	0.373	0.373	0.373	0.373	0.497	0.497	0.497	0.497
Confidence interval	3.513	3.206	3.935	3.739	6.446	4.796	1.184	1.799

cartilage with time [27]. Monaco et al. showed in their experiment that the absence of ACL increases the pivot-shift test results insignificantly, and additional sectioning of the anterolateral ligament increases the pivot-shift test to the 2–3° [28]. So, the results of the anterior cruciate ligament restoration may be improved with the additional plastic repair of the anterolateral ligament or with extra-articular tenodesis. Today, we have a few methods of ALL reconstruction with gracilis or semitendinosus tendon graft simultaneously with the arthroscopic ACL reconstruction [18–20, 29, 30].

The published literature shows that reconstruction of anterolateral ligament improves the post-operative results. One study showed that return to sport (to the pre-injury level) rate was 71% in two years in the group of 83 patients. The results of the anterior drawer test decreased from  $8.0 \pm 1.9$  mm pre-operatively to  $0.7 \pm 0.8$  mm post-operatively; the pivot-shift test value was 0° in 76 patients and 1° in seven patients [30, 31].

Ibrahim et al. conducted a study in two groups of patients. Group 1 (study group) included 53 patients who underwent simultaneous reconstruction of the anterior cruciate ligament together with the reconstruction of anterolateral ligament. Group 2 (control group) included 50 patients who underwent isolated reconstruction of the anterior cruciate ligament. The study showed that the anterior drawer test results decreased to  $1.3 \pm 0.2$  mm in group 1 post-operatively in comparison to  $1.8 \pm 0.8$  mm in group 2 [32].

Mogos et al. described results of surgical treatment of 32 patients who underwent single-step reconstruction of anterior cruciate ligament together with the reconstruction of anterolateral ligament. The post-operative period (12 weeks) showed improvement of IKDC, Tegner, and Lysholm scores, and pivot-shift test, Lachman test, and results of the anterior drawer test decreased from  $7.19 \pm 1.96$  mm (pre-operatively) to  $0.13 \pm 0.34$  mm (12 weeks after the surgery) [33].

Other authors compare the results of arthroscopic ACL reconstruction with the use of patellar tendon graft (group 1), gracilis or semitendinosus tendon graft (group 2), and gracilis or semitendinosus tendon graft for ACL reconstruction together with ALL reconstruction (group 3). This study involved 502 patients with the mean follow-up length of 38.4 months. The study included 39 professional sportsmen. The study showed no statistically significant differences between the groups in IKDC and Tegner Lysholm scores. Ninety-three percent of the patients were able to return to sports, and 64.6% returned to the pre-injury sports activities level. The authors report that five of the 39 professional sportsmen had a recurrent joint injury with the graft tear (3 patients from group 1, 1 patient from group 2, 1 patient from group 3). Also, six patients had injuries that led to a rupture of anterior cruciate ligament of the contralateral limb. The other 28 patients returned to competitions. The rate of the recurrent

graft rupture was 16.77% in group 1, 10.77% in group 2, and 4.13% in group 3. So, the presented data show that ALL reconstruction reduced the risk of ACL graft rupture [31].

Getting back to our study, nine of ten professional sportsmen in group 1 returned to competitions. Ten of ten amateur sportsmen returned to pre-injury sports activity level. Five of ten professional sportsmen in group 2 returned to competitions, and 15 of 20 amateur sportsmen returned to the pre-injury level. The “lack of confidence” of the patients in group 2 may be caused by positive results of the pivot-shift test and Lachman test of various degrees in 24 months after the surgical treatment.

**Study limitations** The study groups were not homogenous. The difference in the patient’s age, number of patients, male to female ratio, and types of sports activities were observed. Concomitant injuries of the knee structures were not considered. The patients with meniscus suture repair were not included in the study. Patients in group 1 were treated by one surgeon, while patients in group 2 (control) were treated by three surgeons of the unit (including the author) with comparable experience and qualification. This publication did not include the evaluation of control MRI of the treated knee joints and the correlation of the surgical treatment outcomes with concomitant defects of the treated knee joint. All these aspects influence the post-operative period, the rehabilitation protocol and terms, and the prognosis, so we cannot provide a straightforward estimate of the results.

But the above results suggest that simultaneous reconstruction of ACL and ALL increases rotational stability of the knee joint, which is of high importance in sports with high torque load. Surgical treatment soon after the injury, in compliance with the recommendations and post-operative rehabilitation, and belief in recovery are thought to allow for complete restoration of the joint function and to decrease psychological discomfort of the patient and risk of the graft rupture [34]. Moreover, the treated joint should be subjected to the same loads as the intact joint, because it leads to equal distribution of the load and decreases the risk of ACL rupture in the contralateral limb.

## Conclusion

The results of the study show that more patients with higher functional demands and more professional sportsmen returned to sports. The medium-term results suggest that reconstruction of the anterior cruciate ligament together with the anterolateral ligament is a promising treatment method for patients with higher functional demands. Despite the results of our and other foreign studies, a need remains for studies that will compare outcomes of ALL reconstruction with the same surgical technique in homogenous groups of patients.

**Funding information** There is no funding source.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

## References

- Sanders TL, Maradit KH, Bryan AJ, Larson DR, Dahm DL, Levy BA, Stuart MJ, Krych AJ (2016) Incidence of anterior cruciate ligament tears and reconstruction: a 21-year population-based study. *Am J Sports Med* 44(6):1502–1507. <https://doi.org/10.1177/0363546516629944>
- Lazishvili GD, Kuzmenko VV, Girshin VE (1997) Arthroscopic reconstruction of the anterior cruciate ligament of the knee. *Vestnik travmatologii and ophthopedii im. Priorova N.N.*, 1:23–27. (in Russian)
- Fedoruk GV, Goleva AV, Brovkin SS, Nevzorov AM (2012) Modern technologies in arthroplasty of the anterior cruciate ligament. *Zemsky Vrach* 2:21–23 (in Russian)
- Davarinos N, O'Neill BJ, Curtin W (2014) A brief history of anterior cruciate ligament reconstruction. *Adv Orthop Surg* 706042. <https://doi.org/10.1155/2014/706042>
- Xie X, Liu X, Chen Z, Yu Y, Peng S, Li Q (2015) A meta-analysis of bone-patellar tendon-bone autograft versus four-strand hamstring tendon autograft for anterior cruciate ligament reconstruction. *Knee* 22(2):100–110. <https://doi.org/10.1016/j.knee.2014.11.014>
- Gudas R, Jurkonis R, Smailys A (2018) Comparison of return to pre-injury sport after 10 mm size bone-patellar tendon-bone (BPTB) versus 8 mm hamstring anterior cruciate ligament reconstruction: a retrospective study with a two-year follow-up. *Med Sci Monit* 24:987–996
- Brophy RH, Schmitz L, Wright RW et al (2012) Return to play and future ACL injury risk after ACL reconstruction in soccer athletes from the multicenter orthopaedic outcomes network (MOON) group. *Am J Sports Med* 40:2517–2522
- Mascarenhas R, Tranovich MJ, Kropf EJ et al (2012) Bone-patellar tendon-bone autograft versus hamstring autograft anterior cruciate ligament reconstruction in the young athlete: a retrospective matched analysis with 2-10 year follow-up. *Knee Surg Sports Traumatol Arthrosc* 20:1520–1527
- Ardern CL (2015) Anterior cruciate ligament reconstruction-not exactly a one-way ticket back to the preinjury level: a review of contextual factors affecting return to sport after surgery. *Sports Health* 7(3):224–230. <https://doi.org/10.1177/1941738115578131>
- Chambat P, Guier C, Sonnery-Cottet B, Fayard JM, Thaumat M (2013) The evolution of ACL reconstruction over the last fifty years. *Int Orthop* 37(2):181–186. <https://doi.org/10.1007/s00264-012-1759-3>
- Nedeff DD, Bach BR (2002) Arthroscopic anterior cruciate ligament reconstruction using patellar tendon autografts. *Orthopedics* 25:343–357 quiz 358-349
- Kocher MS, Steadman JR, Briggs KK, Sterett WI, Hawkins RJ (2004) Relationships between objective assessment of ligament stability and subjective assessment of symptoms and function after anterior cruciate ligament reconstruction. *Am J Sports Med* 32(3):629–634. <https://doi.org/10.1177/0363546503261722>
- Ayeni OR, Chahal M, Tran MN, Sprague S (2012) Pivot shift as an outcome measure for ACL reconstruction: a systematic review. *Knee Surg Sports Traumatol Arthrosc* 20(4):767–777. <https://doi.org/10.1007/s00167-011-1860-y>
- Goncharov EN, Koval OA, Krasnov HO, Mironov AN, Goncharov NG (2018) Topography-anatomical characteristics of anterolateral ligament in knee joint. *Traumatol Orthop Russ* 24(1):88–95. <https://doi.org/10.21823/2311-2905-2018-24-1-88-95> (in Russian)
- Caterine S, Litchfield R, Johnson M, Chronik B, Getgood A (2015) A cadaveric study of the anterolateral ligament: re-introducing the lateral capsular ligament. *Knee Surg Sports Traumatol Arthrosc* 23(11):3186–3195. <https://doi.org/10.1007/s00167-014-3117-z>
- Sonnery-Cottet B, Lutz C, Daggett M, Dalmay F, Freychet B, Niglis L, Imbert P (2016) The involvement of the anterolateral ligament in rotational control of the knee. *Am J Sports Med* 44(5):1209–1214. <https://doi.org/10.1177/0363546515625282>
- Claes S, Luyckx T, Vereecke E, Bellemans J (2014) The Segond fracture: a bony injury of the anterolateral ligament of the knee. *Arthrosc J Arthrosc Related Surg Off Publ Arthrosc Assoc N Am Int Arthrosc Assoc* 30(11):1475–1482. <https://doi.org/10.1016/j.arthro.2014.05.039>
- Smith JO, Yasen SK, Lord B, Wilson AJ (2015) Combined anterolateral ligament and anatomic anterior cruciate ligament reconstruction of the knee. *Knee Surg Sports Traumatol Arthrosc* 23(11):3151–3156. <https://doi.org/10.1007/s00167-015-3783-5>
- Wagih AM, Elguindy AM (2016) Percutaneous reconstruction of the anterolateral ligament of the knee with a polyester tape. *Arthrosc Tech* 5(4):691–697. <https://doi.org/10.1016/j.eats.2016.02.028>
- Chahla J, Menge TJ, Mitchell JJ, Dean CS, LaPrade RF (2016) Anterolateral ligament reconstruction technique: an anatomic-based approach. *Arthrosc Tech* 5(3):453–457. <https://doi.org/10.1016/j.eats.2016.01.032>
- Leiter JR, Gourlay R, McRae S, de Korompay N, MacDonald PB (2014) Long-term follow-up of ACL reconstruction with hamstring autograft. *Knee Surg Sports Traumatol Arthrosc* 22(5):1061–1069. <https://doi.org/10.1007/s00167-013-2466-3>
- Ardern CL, Webster KE, Taylor NF, Feller JA (2011) Return to sport following anterior cruciate ligament reconstruction surgery: a systematic review and meta-analysis of the state of play. *Br J Sports Med* 45(7):596–606. <https://doi.org/10.1136/bjsm.2010.076364>
- Kocher MS, Steadman JR, Briggs K, Zurakowski D, Sterett WI, Hawkins RJ (2002) Determinants of patient satisfaction with outcome after anterior cruciate ligament reconstruction. *J Bone Joint Surg Am* 84-A(9):1560–1572
- Magnussen RA, Lawrence JT, West RL, Toth AP, Taylor DC, Garrett WE (2012) Graft size and patient age are predictors of early revision after anterior cruciate ligament reconstruction with hamstring autograft. *Arthroscopy* 28:526–531
- Mariscalco MW, Flanigan DC, Mitchell J, Pedroza AD, Jones MH, Andrich JT, Parker RD, Kaeding CC, Magnussen RA (2013) The influence of hamstring autograft size on patient-reported outcomes and risk of revision after anterior cruciate ligament reconstruction: a Multicenter Orthopaedic Outcomes Network (MOON) Cohort Study. *Arthroscopy* 29(12):1948–1953. <https://doi.org/10.1016/j.arthro.2013.08.025>
- Van Eck CF, Schkrohowsky JG, Working ZM, Irrgang JJ, Fu FH (2012) Prospective analysis of failure rate and predictors of failure after anatomic anterior cruciate ligament reconstruction with allograft. *Am J Sports Med* 40(4):800–807. <https://doi.org/10.1177/0363546511432545>
- Jonsson H, Riklund-Ahlström K, Lind J (2004) Positive pivot shift after ACL reconstruction predicts later osteoarthritis: 63 patients followed 5-9 years after surgery. *Acta Orthop Scand* 75(5):594–599. <https://doi.org/10.1080/00016470410001484>
- Monaco E, Maestri B, Conteduca F, Mazza D, Iorio C, Ferretti A (2014) Extra-articular ACL reconstruction and pivot shift: in vivo

- dynamic evaluation with navigation. *Am J Sports Med* 42(7):1669–1674. <https://doi.org/10.1177/0363546514532336>
29. Helito CP, Bonadio MB, Gobbi RG, da Mota E Albuquerque RF, Pécora JR, Camanho GL, Demange MK (2015) Combined intra- and extra-articular reconstruction of the anterior cruciate ligament: the reconstruction of the knee anterolateral ligament. *Arthrosc Tech* 4(3):239–244. <https://doi.org/10.1016/j.eats.2015.02.006>
  30. Sonnery-Cottet B, Thauinat M, Freychet B, Pupim BH, Murphy CG, Claes S (2015) Outcome of a combined anterior cruciate ligament and anterolateral ligament reconstruction technique with a minimum 2-year follow-up. *Am J Sports Med* 43(7):1598–1605. <https://doi.org/10.1177/0363546515571571>
  31. Sonnery-Cottet B, Saithna A, Cavalier M, Kajetanek C, Temponi EF, Daggett M, Helito CP, Thauinat M (2017) Anterolateral ligament reconstruction is associated with significantly reduced ACL graft rupture rates at a minimum follow-up of 2 years: a prospective comparative study of 502 patients from the SANTI study group. *Am J Sports Med* 45(7):1547–1557. <https://doi.org/10.1177/0363546516686057>
  32. Ibrahim SA, Shohdy EM, Marwan Y, Ramadan SA, Almisfer AK, Mohammad MW, Abdulsattar WS, Khirat S (2017) Anatomic reconstruction of the anterior cruciate ligament of the knee with or without reconstruction of the anterolateral ligament: a randomized clinical trial. *Am J Sports Med* 45(7):1558–1566. <https://doi.org/10.1177/0363546517691517>
  33. Mogos S, Sendrea B, Stoica IC (2017) Combined anatomic anterior cruciate ligament and anterolateral ligament reconstruction. *Maedica (Buchar)* 12(1):30–35
  34. Ardern CL, Taylor NF, Feller JA, Webster KE (2013) A systematic review of the psychological factors associated with returning to sport following injury. *Br J Sports Med* 47(17):1120–1126. <https://doi.org/10.1136/bjsports-2012-091203>

**Publisher's note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.