

Partial ACL Tears: Anatomic Reconstruction Versus Nonanatomic Augmentation Surgery

ROBERTO BUDA, MD; ALBERTO RUFFILLI, MD; ALESSANDRO PARMA, MD; GHERARDO PAGLIAZZI, MD; DEIANIRA LUCIANI, MD; LAURA RAMPONI, MD; FRANCESCO CASTAGNINI, MD; SANDRO GIANNINI, MD

abstract

Full article available online at [Healio.com/Orthopedics](https://www.healio.com/Orthopedics). Search: 20130821-10

Treatment of partial anterior cruciate ligament (ACL) tears requires ACL remnant preservation. The goal of this study was to compare the outcome of anatomic reconstruction of the torn bundle with nonanatomic augmentation using the over-the-top femoral route. Fifty-two athletes (mean age, 23.3 years) with partial ACL lesions underwent anatomic reconstruction (n=26) or nonanatomic augmentation (n=26). Intraoperative damage of the healthy bundle that required a standard ACL reconstruction occurred in 2 patients in the anatomic reconstruction group. International Knee Documentation Committee (IKDC) score, Tegner score, and arthrometer evaluation were used preoperatively and at follow-up for up to 5 years postoperatively. One failure occurred in the anatomic reconstruction group. Mean IKDC subjective score at follow-up was 88.2 ± 5.7 in the anatomic reconstruction group and 90.2 ± 4.7 in the nonanatomic augmentation group. According to the IKDC objective score at final follow-up, 96% of knees in the nonanatomic augmentation group were normal vs 87.5% in the anatomic reconstruction group. No significant differences were observed between the 2 groups at final follow-up. Anteromedial bundle reconstruction showed significantly lower IKDC subjective and objective scores and higher residual instability values as evaluated with the arthrometer compared with posterolateral bundle reconstruction ($P=.017$). The surgical treatment of ACL partial tears is demanding. Adapted portals, perfect control of the tunnel drilling process, and intercondylar space management are required in anatomic reconstruction. The nonanatomic augmentation technique is simpler, providing excellent durable results over time with a lower complication rate. Anteromedial bundle reconstruction is associated with a poorer outcome, especially when performed with anatomic reconstruction.

The authors are from Rizzoli Orthopaedic Institute, Bologna, Italy.

The authors have no relevant financial relationships to disclose.

Correspondence should be addressed to: Alberto Ruffilli, MD, Rizzoli Orthopaedic Institute, Via Pupilli 1, 40134 Bologna, Italy (aruffilli@tiscali.it).

doi: 10.3928/01477447-20130821-10

Partial lesions of the anterior cruciate ligament (ACL) cause significant knee instability, mainly in young patients with high functional demands, and can evolve into complete tears.^{1,2} The rate of partial tears ranges from 28% to 35%^{3,4} of distortional traumas of the knee with hemarthrosis and from 10% to 28% of all other ACL lesions.⁵ In young, active patients with high functional demands, even after a conservative program, surgical treatment is often required because of a persistence of symptomatic instability.^{6,7}

Various surgical techniques are described in the literature, but agreement exists regarding the need to spare the intact ACL bundle.^{6,8,9} Sparing the intact portion of the ACL has 3 advantages. First, ACL remnants may add biomechanical strength to the reconstruction in the immediate postoperative period, while the graft strength depends primarily on the fixation device. In this period, the augmentation may be protected by the intact remnants and bundle and may allow accelerated rehabilitation and an earlier return to sports.^{6,9,10} Second, the residual portion of the ACL may maintain its blood supply, providing support for the healing process in the graft.^{8,11} Third, saving ACL fibers may maintain some proprioceptive innervation of the ACL. The residual proprioceptive innervation may allow a faster and safer return to sports.^{12,13}

Anatomic reconstruction of a torn bundle is a demanding surgery, and several issues must be taken into account, such as the need for adapted arthroscopic portals, perfect control of the tunnel drilling process to avoid damaging the healthy ACL bundle, and intercondylar space management.¹⁴⁻¹⁶ The nonanatomic over-the-top femoral passage is a valid alternative to perform augmentation of the ACL remnant, thus reducing the technical difficulties encompassed by the anatomic reconstruction technique.

The purpose of this study was to review and compare the 5-year clinical subjective and objective outcomes of 2 groups of pa-

tients affected by unilateral ACL partial lesion. One group underwent anatomic reconstruction of the torn bundle and one underwent nonanatomic augmentation using the over-the-top femoral route. The study also assessed the influence of the torn bundle on the clinical subjective and objective outcomes.

MATERIALS AND METHODS

Patient Data

Fifty-two consecutive male athletes affected by unilateral ACL partial lesions and operated by the same surgeon (R.B.) were included in the study. Twenty-six patients underwent anatomic reconstruction of the torn bundle, and 26 underwent nonanatomic augmentation.

The 2 groups were homogeneous regarding age (mean, 23.6 ± 2.8 years in the anatomic reconstruction group vs 23.7 ± 3.1 years in the nonanatomic augmentation group), injury-surgery interval (mean, 16 weeks in the anatomic reconstruction group vs 18 weeks in the nonanatomic augmentation group), and preinjury sports activity level evaluated by the Tegner activity score (mean, 6.8 ± 0.5 in the anatomic reconstruction group vs 6.7 ± 0.6 in the nonanatomic augmentation group).

Partial ACL tears were defined according to the clinical and arthroscopic criteria described by Barrack et al¹⁷: Lachman's test scores of 0 or 1+ (less than 5 mm); negative or only trace positive pivot shift test; and a significant portion of at least 1 bundle healthy and potentially functional as judged by palpation with a probe and arthroscopic anterior drawer testing.

Patients with preoperative radiographic signs of arthritis, associated chondral lesions evaluated by magnetic resonance imaging, axial deviation of the injured knee, and multidirectional instability were excluded from the study.

The lesion involved the anteromedial band of the ACL in 16 patients and the posterolateral band in 36 patients. Lesions of the posterior horn of the medial meniscus existed in 3 patients (2 in the anatomic

reconstruction group and 1 in the nonanatomic augmentation group), and lesions of the posterior horn of the lateral meniscus existed in 6 patients (2 in the anatomic reconstruction group and 4 in the nonanatomic augmentation group).

Preoperative Assessment

Preoperative evaluation included a complete medical history and physical, radiographic, and magnetic resonance imaging examinations for each patient. International Knee Documentation Committee (IKDC) scores and Tegner scores were assigned to the patients. All patients gave informed consent prior to their inclusion in the study.

SURGICAL TECHNIQUE

Preliminary arthroscopic evaluation was performed by anterolateral and anteromedial portals, while under general or peripheral anesthesia, and with the use of a tourniquet. The entire ACL was examined to assess the extent of ligament damage. Palpation of the residual ligament enabled mechanical strength to be assessed, and the anterior drawer maneuver performed under arthroscopic control provided a functional evaluation. The ACL remnant was also tested with a probe in Cabot's position¹⁸ to tend the fibers. During the arthroscopic examination, any combined intra-articular lesion was treated.

Anatomic Reconstruction

The semitendinosus tendon was harvested, preserving its tibial insertion. The free portion of the tendon was debrided and tacked with 2 nonreabsorbable suture threads.

In anteromedial band reconstruction, a K-wire was placed starting 5 mm medially and 5 mm superiorly to the bone insertion of the gracilis tendon and emerging in the joint 4 to 5 mm lateral to the medial tibial spine and 4 to 5 mm posterior to the anterior rim of the ACL stump. A 7-mm tunnel was reamed over the wire, taking care to avoid damaging the intact bundle. The anterome-

dial band femoral insertion was localized using the remnant fibers (11-o'clock position for right knees and 1-o'clock position for left knees). A 7-mm femoral tunnel was then drilled with an outside-in technique.

In posterolateral band reconstruction, the intra-articular position of the 7-mm tibial tunnel was located in the posterior part of the tibial ACL insertion 5 mm medial to the lateral eminentia intercondylaris. The posterolateral band femoral insertion was localized using the remnant fibers (10-o'clock position for right knees and 2-o'clock position for left knees). A 7-mm femoral tunnel was then drilled with an outside-in technique.

The graft was then passed through the tibial and femoral tunnels using a messenger wire and fixed at the level of the lateral femoral condyle using 1 or 2 titanium staples with the knee bent at 45° for anteromedial band reconstruction and at 20° for posterolateral band reconstruction.

Nonanatomic Augmentation

Both hamstring tendons were harvested, preserving their tibial insertion. The proximal third of the 2 tendons was tacked with 4 nonreabsorbable suture threads.¹⁹

An 8-mm tibial tunnel was drilled starting 5 mm medially and 5 mm superiorly to the bone insertion of the gracilis tendon and emerging in the joint close to the peripheral fibers of the residual portion of the ACL. In anteromedial band reconstruction, the tibial tunnel was in the anatomic footprint of this bundle; in posterolateral band reconstruction, the tibial tunnel emergence was just posterolateral to the insertion of the anteromedial band.

Then, the intra-articular passage for the graft was identified between the ACL and posterior cruciate ligament at the level of the intercondylar notch; this passage was not dependent on the bundle that had to be reconstructed. Through this passage, the lateral surface of the distal femur was reached, where the tendon graft was anchored by 2 metal staples in an over-the-top position. The remaining portion of the tendons was

taken backward, anchored to a thread, and fixed by tenodesis on the anatomic insertion of the hamstring tendons. In anteromedial band reconstruction, the graft was placed in an 11- or 1-o'clock position, running parallel to the residual posterolateral band. In posterolateral band reconstruction, the graft was not placed in a 10- or 2-o'clock position because of the presence of the residual anteromedial band; a more vertical graft bridging and tensioning of the anteromedial band were obtained.

Postoperative Treatment

The postoperative protocol was the same for both techniques. Postoperatively, a rigid extension brace was worn overnight to avoid joint flexion contracture. The morning after surgery, the drainage was removed, and patients began continuous passive motion; the degree of joint movement allowed on postoperative day 1 was between 0° and 40°. Thirty-six hours postoperatively, patients were discharged and allowed to load the limb progressively, using the brace and 2 forearm crutches. Patients underwent home rehabilitation for the next 15 days. After 2 weeks, full weight bearing was allowed without the brace. With the help of a physical therapist, patients began rehabilitation by performing closed-chain kinetic exercises in postoperative weeks 3 and 4, and then open-chain kinetic exercises were performed. Return to competitive sports was allowed 3 months postoperatively.

Postoperative Evaluation

All patients were reassessed immediately postoperatively and at each follow-up for up to 5 years postoperatively. International Knee Documentation Committee scores and Tegner scores were assigned to the patients. Arthrometric assessment was performed immediately postoperatively and at each follow-up for up to 5 years postoperatively with the KT-1000 arthrometer (MEDmetric Corporation, San Diego, California) by means of the manual maximum displacement test.

The results were analyzed statistically to evaluate differences between the 2 groups in terms of subjective outcomes and stability. The analysis also assessed the possible influence of the type of torn bundle on the outcome. The difference between groups regarding continuous variables was assessed by 1-way analysis of variance if the variables presented a normal distribution evaluated by Kolmogorov-Smirnov test. Conversely, if the variables did not present a normal distribution, the nonparametric Mann-Whitney test was used. The difference between groups regarding dichotomic variables was assessed by Fisher exact test and chi-square test. The possible influence of the groups on ordinal outcomes was assessed with Kendall tau-b ordinal correlation.

Statistical analysis was performed with SPSS version 15.0 software (SPSS Inc, Chicago, Illinois). For all tests, a *P* value less than .05 was considered significant.

RESULTS

Intraoperative damage of the healthy bundle occurred in 2 patients in the anatomic reconstruction group. In these cases, standard ACL reconstruction was used, and the patients were excluded from the study. No postoperative complications were observed. No additional traumatic events were reported in any patient up to 5 years postoperatively. One failure due to laxity recurrence was observed at final follow-up in the anatomic reconstruction group.

Mean IKDC subjective score at final follow-up was 88.2±5.7 in the anatomic reconstruction group and 90.2±4.7 in the nonanatomic augmentation group. According to the IKDC objective score, at final follow-up, 46 patients were rated A (21 in the anatomic reconstruction group and 25 in the nonanatomic augmentation group), 3 patients were rated B (2 in the anatomic reconstruction group and 1 in the nonanatomic augmentation group), and 1 patient was rated C (anatomic reconstruction group) (Table 1).

Table 1

IKDC Objective Score at Final Follow-up

Surgical Technique	Reconstructed Bundle	IKDC Score			
		A	B	C	D
Anatomic reconstruction	Anteromedial (n=9)	6	2	1	–
	Posterolateral (n=15)	15	–	–	–
Nonanatomic augmentation	Anteromedial (n=7)	6	1	–	–
	Posterolateral (n=19)	19	–	–	–

Abbreviation: IKDC, International Knee Documentation Committee.

Table 2

Ligament Stability Evaluation at 5-year Follow-up

Surgical Technique	Reconstructed Bundle	Lachman's Test				Pivot Shift Test			
		A	B	C	D	A	B	C	D
Anatomic reconstruction	Anteromedial (n=9)	7	1	1	–	6	2	1	–
	Posterolateral (n=15)	15	–	–	–	15	–	–	–
Nonanatomic augmentation	Anteromedial (n=7)	7	–	–	–	6	1	–	–
	Posterolateral (n=19)	19	–	–	–	19	–	–	–

Table 3

KT-1000 Immediate Postoperative and Follow-up Evaluations

Surgical Technique	Reconstructed Bundle	Postoperative			Final Follow-up		
		0-3 mm	3-5 mm	>5 mm	0-3 mm	3-5 mm	>5 mm
Anatomic reconstruction	Anteromedial (n=9)	8	1	–	7	1	1
	Posterolateral (n=15)	15	–	–	15	–	–
Nonanatomic augmentation	Anteromedial (n=7)	7	–	–	7	–	–
	Posterolateral (n=19)	19	–	–	19	–	–

tion group) (Table 2).

Arthrometric evaluation performed with the KT-1000 at final follow-up showed a mean side-to-side difference of 0.9 ± 1.0 mm in the anatomic reconstruction group and 0.8 ± 0.6 mm in the nonanatomic augmentation group (Table 3).

Mean postoperative sport activity at final follow-up according to the Tegner activity score was 6.6 ± 0.6 in the anatomic reconstruction group and 6.6 ± 0.5 in the nonanatomic augmentation group. Two patients (1 in the anatomic reconstruction group and 1 in the nonanatomic augmentation group) quit sport activity. Four patients (3 in the anatomic reconstruction group and 1 in the nonanatomic augmentation group) resumed sport activity at a lower level for fear of reinjury, whereas the remaining 44 patients (20 in the anatomic reconstruction group and 24 in the nonanatomic augmentation group) resumed sport activity at their preinjury level. No significant difference in subjective or objective outcome was observed between the 2 groups at final follow-up.

The reconstructed bundle statistically affected the outcome. Patients who underwent posterolateral band reconstruction had higher IKDC subjective and objective scores ($P = .006$ and $.017$, respectively) and lower KT-1000 side-to-side differences ($P = .001$) compared with patients who underwent anteromedial band reconstruction.

DISCUSSION

Partial ACL lesions represent a challenging pathology.⁶⁻⁹ The current international literature agrees on the need to spare the intact bundle of the partially torn ACL to increase the biomechanical strength of the reconstruction in the early postoperative period and to maintain ACL blood supply and proprioception.^{8,10-16} Many authors have described augmentation techniques to restore knee kinematics, thus maintaining the graft remnant.^{15,20} Most techniques are intended to obtain an anatomic reconstruction of the torn bundle. This surgery is technically challenging,

According to Lachman's test and the pivot shift test performed immediately postoperatively, 51 [AQ: Number in each group?] patients were rated A and 1 patient (in the anatomic reconstruction group) was rated B. According to Lachman's test performed at final follow-up, 1 patient was rated B and 1 patient was rated C (both in the anatomic reconstruction group); according to the pivot shift test, 3 patients were rated B (2 in the anatomic reconstruction group and 1 in the nonanatomic augmentation group) and 1 patient was rated C (anatomic recon-

requiring adapted portals, perfect control of the instruments during tunnel reaming, and intercondylar space management, which is crucial, especially when dealing with small knees. Augmentation of the torn bundle using the over-the-top femoral passage, avoiding femoral tunnel reaming, may represent a solution able to overcome the majority of technical difficulties encompassed by anatomic techniques.¹⁹

The goal of the current study was to compare the clinical outcome of anatomic reconstruction of the torn bundle with nonanatomic augmentation using the over-the-top femoral route. Although no statistically significant differences emerged in terms of subjective and objective outcomes between the 2 techniques, at long-term follow-up a higher rate of mild instability was observed in the anatomic reconstruction group (3 patients, 1 rated C and 2 rated B according to the IKDC score) compared with the nonanatomic augmentation group (1 patient, rated B according to the IKDC score). In addition, 2 patients who underwent anatomic reconstruction experienced iatrogenic damage of the healthy bundle during femoral tunnel reaming. These cases were shifted to standard ACL reconstruction. No intraoperative complications occurred in the nonanatomic augmentation group, although a lower laxity recurrence was observed at follow-up.

Statistical analysis showed that reconstruction of the anteromedial band was related to a significantly poorer outcome. The worst results in the current series occurred in patients who underwent anatomic reconstruction of the torn anteromedial band.

The anatomic reconstruction technique is more invasive than nonanatomic augmentation. The need to ream a tunnel in the anatomic position on the femoral side may risk damage to the vascular supply to the healthy bundle, thus resulting in further degeneration of the conserved bundle. In addition, the anatomic reconstruction technique encompasses reconstruction

with a single-strand semitendinosus graft, whereas the nonanatomic augmentation technique allows augmentation of the partially torn ACL with a double-strand hamstrings tendon graft. Degeneration of the healthy bundle caused by the invasiveness of the anatomic reconstruction technique associated with the lower mechanical strength offered by the single-strand reconstruction may be a cause of the higher rate of mild instability observed in the anatomic reconstruction group at long-term follow-up. In particular, when reconstructing the anteromedial band bundle with anatomic reconstruction, degeneration of the healthy posterolateral band may risk development of rotational instability at follow-up.

Correct evaluation of the graft remnant is challenging. Ohsawa et al²¹ reported that it is difficult for even a skilled arthroscopic surgeon to determine the efficacy of the residual bundle, which can be taut, slightly lax, or lax. Performing anatomic reconstruction of only 1 bundle with an associated underestimated inefficacy of the graft remnant may risk failure. Conversely, the nonanatomic augmentation technique has been widely described as an excellent surgical option, even in cases of complete ACL tears, thus reducing the risk of potential failure when applied in the treatment of partial tears.²²⁻²⁵ The nonanatomic augmentation technique is not able to ensure correct positioning of the posterolateral band. The graft cannot be placed in the 10-o'clock position (for a right knee) because of the presence of the residual anteromedial band; therefore, the reconstructed bundle is more vertical, bridging and tensioning the residual anteromedial band. The posterolateral band has been proven to be important when the knee is subjected to combined rotatory loads, such as those produced in a pivot shift, and especially with the knee near full extension^{15,19-22}; reconstruction of this bundle in the correct position is advisable. The current authors accepted this drawback of the nonanatomic augmentation

technique because in partial ACL tears, the rotatory instability is minimal or absent (the pivot shift test is always negative or only trace positive),¹⁹ so reconstruction of the posterolateral band with the graft at the 10-o'clock position is not strictly required in these cases.

The recent development of more sophisticated instrumentation, such as pins that become retrograde reamers to drill the femoral tunnel using a translateral approach, may reduce the invasiveness of anatomic reconstruction, thus obtaining better results.²⁶ Comparative studies using these tools must be performed to validate this hypothesis.

The current study had some limitations. First, the investigation was only concerned with clinical results; second-look arthroscopies to evaluate ACL remnant morphology would add important information. In addition, computed tomography scan of the operated knees would be useful to better define tunnel position, especially on the femoral side in the group of patients undergoing anatomic reconstruction.

Second, the diagnosis of rotational instability was made clinically with the pivot shift test without the use of an electromagnetic measurement system.^{27,28} However, multiple skilled surgeons (R.B., S.G.) examined the pivot shift test in these patients.

Third, the number of cases was limited to 52 patients. The study showed no significant difference between the 2 techniques, although a higher complication rate and higher laxity recurrence at follow-up was observed in patients who underwent anatomic reconstruction. This finding may be related to the small number of patients enrolled in the study.

CONCLUSION

The nonanatomic augmentation technique is simpler than the anatomic reconstruction technique, providing excellent durable results over time with a lower complication rate. Anteromedial bundle

reconstruction is associated with a poorer outcome, especially when performed with anatomic reconstruction. A comparative prospective study with a large cohort of patients should be performed to validate these findings. 

REFERENCES

- Fritschy D, Panoussopoulos A, Wallensten R, Peter R. Can we predict the outcome of a partial rupture of the anterior cruciate ligament? A prospective study of 43 cases. *Knee Surg Sports Traumatol Arthrosc.* 1997; 5(1):2-5.
- Noyes FR, Mooar LA, Moorman CT III, McGinniss GH. Partial tears of the anterior cruciate ligament. Progression to complete ligament deficiency. *J Bone Joint Surg Br.* 1989; 71(5):825-833.
- Noyes FR, Bassett RW, Grood ES, Butler DL. Arthroscopy in acute traumatic hemarthrosis of the knee. Incidence of anterior cruciate tears and other injuries. *J Bone Joint Surg Am.* 1980; 62(5):687-695.
- Noyes FR, Paulos L, Mooar LA, Signer B. Knee sprains and acute knee hemarthrosis: misdiagnosis of anterior cruciate ligament tears. *Phys Ther.* 1980; 60(12):1596-1601.
- Jacquot L, Selmi TAS, Servien E, Neyret P. Lésions ligamentaires récentes du genou. *Encyclopédie Médico-chirurgicale Appareil Locomoteur. Editions Scientifiques et Médicales.* Paris, France: Elsevier SAS; 2003:14-080-A-20.
- Bak K, Scavenius M, Hansen S, et al. Isolated partial rupture of the anterior cruciate ligament. Long term follow-up of 56 cases. *Knee Surg Sports Traumatol Arthrosc.* 1997; 5(2):66-71.
- Buda R, Di Caprio F, Giuriati L, Luciani D, Busacca M, Giannini S. Partial ACL ruptures augmented with distally inserted hamstring tendons and over-the top fixation: an MRI evaluation. *Knee.* 2008; 15(2):111-116.
- Bray RC, Leonard CA, Salo PT. Vascular physiology and long-term healing of partial ligament tears. *J Orthop Res.* 2002; 20(5):984-989.
- Liu W, Maitland ME, Bell GD. A modeling study of partial ACL injury: simulated KT-2000 arthrometer tests. *J Biomech Eng.* 2002; 124(3):294-301.
- Crain EH, Fithian DC, Paxton EW, Luetzow WF. Variation in anterior cruciate ligament scar pattern: does the scar pattern affect anterior laxity in anterior cruciate ligament-deficient knees? *Arthroscopy.* 2005; 21(1):19-24.
- Dodds JA, Arnoczky SP. Anatomy of the anterior cruciate ligament: a blueprint for repair and reconstruction. *Arthroscopy.* 1994; 10(2):132-139.
- Adachi N, Ochi M, Uchio Y, Iwasa J, Ryoke K, Kuriwaka M. Mechanoreceptors in the anterior cruciate ligament contribute to the joint position sense. *Acta Orthop Scand.* 2002; 73(3):330-334.
- Schultz RA, Miller DC, Kerr CS, Micheli L. Mechanoreceptors in human cruciate ligaments. A histological study. *J Bone Joint Surg Am.* 1984; 66(7):1072-1076.
- Ochi M, Adachi N, Deie M, Kanaya A. Anterior cruciate ligament augmentation procedure with a 1-incision technique: anteromedial bundle or posterolateral bundle reconstruction. *Arthroscopy.* 2006; 22(4):463.e1-463.e5.
- Siebold R, Fu FH. Assessment and augmentation of symptomatic anteromedial or posterolateral bundle tears of the anterior cruciate ligament. *Arthroscopy.* 2008; 24(11):1289-1298.
- Sonnery-Cottet B, Lavoie F, Ogassawara R, Scussiato RG, Kidder JF, Chambat P. Selective anteromedial bundle reconstruction in partial ACL tears: a series of 36 patients with mean 24 months follow-up. *Knee Surg Sports Traumatol Arthrosc.* 2010; 18(1):47-51.
- Barrack RL, Buckley SL, Bruckner JD, et al. Partial versus complete acute anterior cruciate ligament tears. The results of nonoperative treatment. *J Bone Joint Surg Br.* 1990; 72(4):622-624.
- Sonnery-Cottet B, Chambat P. Arthroscopic identification of the anterior cruciate ligament posterolateral bundle: the figure-of four position. *Arthroscopy.* 2007; 23(10):1128.e1-1128.e3.
- Buda R, Ferruzzi A, Vannini F, Zambelli L, Di Caprio F. Augmentation technique with semitendinosus and gracilis tendons in chronic partial lesions of the ACL: clinical and arthrometric analysis. *Knee Surg Sports Traumatol Arthrosc.* 2006; 14(11):1101-1107.
- Ochi M, Adachi N, Uchio Y, et al. A minimum 2-year follow-up after selective anteromedial or posterolateral bundle anterior cruciate ligament reconstruction. *Arthroscopy.* 2009; 25(2):117-122.
- Ohsawa T, Kimura M, Kobayashi Y, Hagiwara K, Yorifuji H, Takagishi K. Arthroscopic evaluation of preserved ligament remnant after selective anteromedial or posterolateral bundle anterior cruciate ligament reconstruction. *Arthroscopy.* 2012; 28(6):807-817.
- Brower RS, Melby A III. In vitro comparison of over-the-top and through-the-condyle anterior cruciate ligament reconstruction. *Am J Sports Med.* 1992; 20(5):567-574.
- Karlson JA, Steiner ME, Brown CH, Johnston J. Anterior cruciate ligament reconstruction using gracilis and semitendinosus tendons: comparison of through-the-condyle and over-the-top graft placements. *Am J Sports Med.* 1994; 22(5):659-666.
- Marcacci M, Zaffagnini S, Giordano G, Iacono F, Presti ML. Anterior cruciate ligament reconstruction associated with extra-articular tenodesis: a prospective clinical and radiographic evaluation with 10- to 13-year follow-up. *Am J Sports Med.* 2009; 37(4):707-714.
- Marcacci M, Zaffagnini S, Iacono F, Vascellari A, Loreti I, Kon E, Presti ML. Intra- and extra-articular anterior cruciate ligament reconstruction utilizing autogeneous semitendinosus and gracilis tendons: 5-year clinical results. *Knee Surg Sports Traumatol Arthrosc.* 2003; 11(1):2-8.
- Lubowitz JH, Ahmad CS, Anderson K. All-inside anterior cruciate ligament graft-link technique: second-generation, no-incision anterior cruciate ligament reconstruction. *Arthroscopy.* 2011; 27(5):717-727.
- Kubo S, Muratsu H, Yoshiya S, Mizuno K, Kurosaka M. Reliability and usefulness of a new in vivo measurement system of the pivot shift. *Clin Orthop Relat Res.* 2007; (454):54-58.
- Lopomo N, Signorelli C, Bonanzinga T, Marcheggiani Muccioli GM, Visani A, Zaffagnini S. Quantitative assessment of pivot-shift using inertial sensors. *Knee Surg Sports Traumatol Arthrosc.* 2012; 20(4):713-717.